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Nutrients algae and beneficial use support assessment of the Boulder River

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Nutrients, Algae and Beneficial Use Support Assessment of the Boulder River

by

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From 1996 to the present, the Boulder River, a tributary to the Yellowstone River near Big Timber, Montana, was listed by the state of Montana as impaired by dewatering in its lower 5 miles. The remainder of the river has never appeared on the state's list of impaired waters, but reports of nuisance algae blooms by local residents beginning in the early 1990's indicated that the Boulder might be suffering from nutrient impairment, particularly in the area upstream of Natural Bridge. In response, the Montana Department of Environmental Quality (DEQ) and the Sweet Grass Conservation District agreed to sponsor and fund this study of the Boulder River to investigate the algae bloom and nutrient concentrations in the river. At the time, little information existed with which to determine whether the Boulder Rive supported its beneficial uses; hence the sponsors also requested that the study gather sufficient and credible data for making a use support determination. The objectives of this study included the following: 1) provide an initial assessment of the reported algae blooms in the Boulder River and explore the possibility that human-caused nutrient sources were fueling the algae bloom; 2) gather sufficient and credible data with which to evaluate support of beneficial uses in the Boulder River; and 3) provide baseline data for comparison with future water quality studies of the river.

Synoptic sampling for nutrients (nitrate+nitrite, total Kjeldahl nitrogen, and total phosphorous) was performed approximately monthly from August 1999 through October 2001 at sites along the river that bracketed suspected sources. No significant human-caused sources of nutrients were detected during this study. Moreover, instream nutrient and algal levels did not violate the only standards currently set for these parameters in Montana. However, nutrient levels did sometimes exceed levels recommended by the EPA for this area. In late spring of 2000 and 2001, the alga *Ulothrix zonata* was highly visible in isolated patches throughout the upper river above Natural Bridge. However, *Ulothrix* levels did not appear to be correlated with development in the upper watershed or with nutrient concentrations.

The Montana Department of Environmental Quality's beneficial use support determination assessment was performed at seven locations in August 1999. The assessment consisted of a suite of chemical, biological, and physical parameters. The weight of evidence provided by this assessment suggested that the Boulder River fully supported aquatic life and other beneficial uses in 1999; however, the river below Natural Bridge appeared to be near the threshold of minor impairment. To maintain water quality in the Boulder Watershed, a watershed group has recently been formed. Maintaining instream flows and protecting riparian areas from development and overgrazing are key parts of a strategy to maintain water quality in the Boulder.

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I would like to thank my committee members, Dr. Vicki Watson, Dr. Scott Woods, Dr. Tom Roy, and Pat Newby for their assistance with this project. Tami Tragakiss provided continuous logistical support and good company. Thanks to the Sweet Grass Conservation District for agreeing to sponsor the study and to the Montana Department of Environmental Quality, the U. S. Environmental Protection Agency, and the University of Montana Environmental Studies Program for funding this work.

This is the final report required by the Boulder River study agreement between the Sweet Grass Conservation District and the Montana Department of Environmental Quality (DEQ Contract No. 200064, Federal Catalog No. 66.460).

INTRODUCTION

The Boulder River is currently listed by the state of Montana as impaired by dewatering in its lower 5 miles. The listing decision is based on reports by Montana Fish Wildlife and Parks (FWP) that the construction of gravel diversion dikes across the entire river channel to divert water flow to irrigation ditches was creating problems for migrating fish. The remainder of the river has never appeared on the state's list of impaired waters, but reports of nuisance algae blooms by local residents beginning in the early 1990's indicated that the Boulder might be suffering from nutrient impairment, particularly in the area upstream of Natural Bridge. In response, the Montana Department of Environmental Quality (DEQ) and the Sweet Grass Conservation District agreed to sponsor and fund this study of the Boulder River to investigate the reported blooms and the nutrient concentrations in the river. At the time, little information existed with which to determine whether the Boulder River supported its beneficial uses; hence the sponsors also requested that the study gather sufficient and credible data for making a use support determination.

The rationale for determining whether waters support beneficial uses comes from the Federal Clean Water Act, aims to "...restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Gallagher 1996). As part of its effort to accomplish this goal, the Environmental Protection Agency (EPA) has instructed the states to establish water quality standards using federal guidelines. First, the states must classify all water bodies according to their beneficial uses, including "public drinking water supplies, propagation of fish and wildlife, recreational purposes, and industrial, agricultural and other uses" (Gallagher 1996). Second, the states must develop quantitative water quality criteria which, if met, can reasonably be expected to ensure that beneficial uses are supported. For each water body that violates its water quality standards and/or fails to support its beneficial uses, the states are required to determine what actions (including pollution reduction and/or habitat restoration) are needed to restore the waterbody's integrity (i.e. meet its standards and fully support uses). Making this determination and developing a plan to achieve this restoration is called a TMDL, or Total Maximum Daily Load, referring to the maximum load of stress the waterbody can withstand without unacceptable change. The Clean Water Act also requires states to complete a list of water bodies that are impaired (not fully supporting uses) and in need of TMDL's. The list of impaired waters is called the 303(d) list after the section of the act that requires the development of such lists.

STUDY OBJECTIVES

The objectives of this study included the following:

1. Provide an initial assessment of the reported algae blooms in the Boulder River above Natural Bridge. Although DEQ had already conducted a brief nutrient study of this section of the river in 1994, which found no indication of elevated nutrient levels (Levine, 1996), little information existed on the type of algae causing the complaints, the locations of the algae blooms, or the extent of the algal growth. The assessment described in this report was intended to provide this information, and to explore the possibility that anthropogenic nutrient sources were causing the algae bloom.

2. Gather sufficient and credible data with which to make a beneficial use determination and determine the 303(d) status of the Boulder River.
3. Provide baseline data for comparison with future water quality studies of the river.

DESCRIPTION OF THE BOULDER RIVER DRAINAGE

Located in Park and Sweet Grass Counties in south-central Montana, the Boulder River drains approximately 583 square miles of national forest and private lands south of Big Timber, Montana (**Figure 1**). From its headwaters in the Absaroka-Beartooth Wilderness, the Boulder flows north for approximately 65 miles before joining the Yellowstone River. Major tributaries include the East and West Forks of the Boulder. Elevation in the watershed ranges from approximately 4,050 at the Yellowstone River to over 10,000 feet in the Absaroka Mountains.

The Boulder River is classified as a B-1 stream by the State of Montana, indicating high water quality and potential to support of a wide range of beneficial uses, including domestic use, recreation, agricultural and industrial water supply, and wildlife and aquatic life (including coldwater fishery).

The Boulder River and its floodplain are naturally divided into two sections by a waterfall located just downstream of Natural Bridge near the Gallatin National Forest Boundary. Above Natural Bridge, the Boulder flows through a steep, forested canyon. Rosgen B channel types (Rosgen 1996) dominate, with substrates ranging from coarse gravels to large cobbles. Land ownership in this area is dominated by the United States Forest Service, which controls the Gallatin National Forest and the Absaroka-Beartooth

Wilderness. Except for a gravel road that parallels the Boulder River almost to its headwaters, forest and wilderness lands in this area are roadless, and land uses are limited primarily to recreation, although some historic mining has occurred in the Boulder River's headwaters. Several large church camps and housing developments and a few scattered private residences are located on private lands adjacent to the Boulder above Natural Bridge. This part of the Boulder River contains several areas of development that were suspected as possible nutrient sources, including Aspen Campground, Clydehurst church camp, Fall Creek Campground, and the Whispering Pines Housing Development. All of these were bracketed with nutrient sampling stations as discussed in more detail later in this report.

Below Natural Bridge, the Boulder flows through a relatively wide valley, dominated by private agricultural lands used for sheep and cattle grazing and hay production. From Natural Bridge downstream to the confluence of the East Boulder River, the Boulder River is a Rosgen C-type channel, with a substrate of coarse gravel and small cobbles. Below the East Boulder, the Boulder River increases in gradient, and returns to a Rosgen B-type channel, with substrate dominated by large cobbles and small boulders. A map showing the location of the watershed is presented in **Figure 1**.

Climate in the Boulder River Watershed varies greatly with elevation as is typical of the mountains regions of Montana. Low valleys in the watershed are semi-arid, while the highest elevations approach sub-arctic conditions (Stillwater 1992). At the National Oceanic and Atmospheric Administration (NOAA) weather station in Big Timber (elevation 4,500 ft), average maximum temperatures climb to nearly 90 degrees F in July and reach a low of 16 degrees F in January. The average annual maximum and minimum temperatures at the Big Timber station are 60.5 and 33.6 degrees F, respectively. Average annual precipitation at Big Timber is 15.31 inches, with April, May, and June the wettest months. Precipitation in the highest parts of the watershed reaches as much as 55 inches annually (NRIS 2003).

Vegetative data were summarized from GAP information for the Boulder Watershed. GAP vegetation classification was developed by the United Stated Geologic Survey (USGS) from satellite imagery in the 1990s. In general, coniferous trees dominate the plant communities upstream of Natural Bridge, while grasslands dominate below (**Figure 2**) (NRIS 2003). Five GAP vegetation-mapping units cover approximately 60% of the watershed: Mixed Whitebark Pine Forest (17.6%), Mixed Subalpine Forest (12.6%), Low/Moderate Cover Grasslands (11.3%), Douglas-fir (9.3%), and Lodgepole Pine (9.0%). Rock accounts for approximately 10%, and the remaining 30% of the watershed area is comprised of a mixture of small amounts of 32 other GAP mapping vegetation types (**Table 1**).

Nearly half of the watershed (47 %) is underlain by calc-alkaline intrusive rocks, primarily granodiorite and diorite **(Figure 3, Table 2)**. Calc-alkaline volcanoclastics occupy another 12.6% of the watershed. From Natural Bridge to the confluence of the East Boulder, the Boulder River flows through a mix of geologic materials including ultramafics, mixed miogeosynclinals, carbonate, granitic gneiss, sandstone, and glacial till. Below its confluence with the East Boulder, the Boulder River floodplain is dominated by alluvial materials. Geologic mapping units are defined in **Table 3**.

Fourteen Natural Resource Conservation Service (NRCS) soil mapping units occur within the Boulder River Watershed (**Figure 4** and **Table 4**). Three mapping units dominate the Boulder Watershed: Shadow-Garlet-Macfarlane, Rock Outcrop-Rubble land-Cowood, and Absarokee-Hilger-Big Timber. These three units comprise 60.8% of the watershed (NRIS 2003).

MONITORING AND ASSESSMENT DESIGN AND METHODS

Fourteen sampling stations were positioned between the headwaters of the Boulder River and its confluence with the Yellowstone River to characterize the range of conditions in the Boulder and to bracket suspected nutrient sources (**Figure 5** and **Table 5**). Seven of the sites were established during an initial reconnaissance of the river in August 1999. The remaining seven sites were established during subsequent sampling occasions in response to observed potential nutrient sources, suggestions from local residents, and areas of noticeable algal growth. For this reason, number of samples varies somewhat between sites. Sampling was conducted in August 1999, and then approximately monthly between April 2000 and October 2001, except when winter conditions made sampling too difficult. Much of the discussion that follows refers to Natural Bridge as a landmark. Please note that the first site downstream of Natural Bridge is site 11 (Hass Ranch).

Water column grab samples were collected at each site and analyzed for total Kjeldahl nitrogen (TKN), nitrate plus nitrite ($NO_{2/3}$), and total phosphorous (TP). Sample results for TKN and $NO_{2/3}$ were summed to estimate total nitrogen (TN). Soluble reactive phosphorous (SRP) was not sampled due to equipment and budgetary constraints. Stream flow was not measured at each site, but the United States Geological Survey's gauge at Big Timber provided a measure of the relative magnitude of flow over the sampling period.

DEQ's standard method of assessing beneficial use support was performed in August 1999 at seven of the 14 sites. DEQ's standard methods can be reviewed online at http://www.deq.state.mt.us/ppa/mdm/SOP/sop.asp, and example DEQ field forms used in this study are included in **Appendix A**. Sites included in the DEQ stream assessment were Basin Creek (site 1), Aspen Campground (site 6), Aller Ranch (site 10), Hass Ranch (site 11), Below East Boulder (site 12), 8 Mile Bridge (site 13), and Near the Mouth (site 14). The protocols included the collection and analysis of: periphyton, macroinvertebrate community composition, and late-summer stream-bottom chlorophyll a levels, metals concentrations in fine bed sediments (< 0.062 mm), and water column samples. This last was analyzed for a broad suite of water chemistry parameters, including total metals, common ions, total suspended solids (TSS), and total dissolved solids (TDS). The first set of the monthly nutrient samples was also collected in August 1999.

In light of the numerous complaints of profuse algal growth from local residents, algal and chlorophyll a levels were surprisingly low when sampled in August 1999, and filamentous algae was not noticeable to the casual observer. As a result, a visual inspection of the river was conducted during each of the subsequent nutrient sampling occasions to determine the timing and location of the algal growths that had raised local concern. In June of 2000 and 2001, noticeable levels of the filamentous algae *Ulothrix zonata* were observed in the Boulder upstream of Natural Bridge. In both years, the river was visited several times during the approximate two-week period when the *Ulothrix* growth was most profuse, and chlorophyll a samples were collected when algal levels appeared to have reached their maximum levels based on visual observation.

For the August 1999 sampling, algal biomass samples were collected by the method described in Watson and Gestring (1996). Streambed cobbles between 10 and 20 cm in size were selected randomly from areas between 20 and 40 cm in depth where water velocities were between 0.3 and 0.6 m/s. A flexible template with a window 2x2 inches was placed on each rock and the attached algal material was scraped off with a single edge razor blade. At each site, fifteen samples were collected over an area of at least 10x10 meters. These samples were stored frozen until analyzed. The analytical lab composited all the samples from a site and reported a single value; hence there is no measure of variability at each site. For the *Ulothrix* sampling in 2000 and 2001, samples were collected in a similar manner except that sampling was not random, but instead focused on the areas of heaviest algal growth, and thus results represent the maximum concentrations present on those sampling dates.

The August 1999 DEQ stream assessment also included a one-time assessment of the physical habitat of the Boulder River and its riparian areas using DEQ's standard method, which is included in **Appendix A**. This semi-quantitative assessment evaluates how similar a site is to a reference site or composite reference for the ecoregion and produces a numerical score of the physical health of the stream reach that is calculated as a percent of the maximum score possible (assuming reference has maximum score). Typically, sites with scores greater than or equal to 75% of maximum values are considered to be functioning properly by the DEQ. For the purpose of the physical assessment, the Boulder was divided into 7 reaches based on similar watershed characteristics and land use. In each reach, the habitat was evaluated at each public access point and on private property where access was granted, and the final score is assumed to reflect the "typical" condition of the reach based on this inventory. Aerial photographs were used to interpret average riparian width and condition for each reach and to confirm that sites that were visited on the ground were representative of the reach in which they occurred.

All water quality samples were collected and preserved according to methods described in MDEQ's Standard Operating Procedures Manual (MDEQ 1999), which is EPA approved. All water samples were sent to Energy Laboratories, Inc., an EPA approved laboratory, for analysis. A list parameters and analysis methods is presented in **Appendix B.**

Macroinvertebrate samples were analyzed by Wease Bollman of Rhithron Biological Associates, and periphyton samples were analyzed by Loren Bahls, Ph.D. of Hannaea. Bollman and Bahls are respected taxonomists who have developed a series of metrics that allow them to evaluate stream condition and causes of impairment from the species composition of macroinvertebrate and periphyton community samples. DEQ and numerous other state and federal agencies rely on these professionals.

Fine bed-sediment samples were collected from depositional areas and filtered through a 0.062 mm filter using river water to wash the sediment through the filter. At each site where fine bed sediment was sampled, small amounts of sediment were collected from a random spot in each of five different depositional areas, and these five samples were composited to form a single sample. Samples were stored unpreserved until analyzed. The analysis method appears in the lab's data sheets in **Appendix C**.

RESULTS AND DISCUSSION

Streamflow

Streamflow on the Boulder River has been measured by the United States Geological Survey (USGS) at its gauging station near Big Timber, near the mouth of the river, since 1948 (**Figure 6**). Over the period of record, discharge in the winter months has averaged between 100 and 150 cubic feet per second (cfs). Spring runoff begins in April, with peak flows averaging 2771 cfs. The falling limb of the hydrograph begins in late June or early July; late summer and fall flows average approximately 200 cfs.

In 1999, the first year of the study, discharge was very similar to the long term average, with slightly below average flows in the late summer and early fall of that year. However, in 2000 and particularly in 2001, stream flow at Big Timber was well below the long term average for the Boulder River. Peak flows reached only 2,181 and 1484 cfs in 2000 and 2001 respectively, and streamflow dropped as low as 25.5 cfs in August 2001. On all occasions except the first sampling date, stream flows in the Boulder were below average when water sampling was conducted (**Table 6**).

Although below average flows in the Boulder River characterized the study period, 1997 was an unusually high flow year for the Boulder. Stream flow on June 5, 1997 was 9,940 cfs, the highest ever recorded at the USGS gauge at Big Timber. It is possible that this flood could have scoured away the high algal levels that drew complaints in the early and mid 1990s, and algal levels may not have recovered by the time of this study.

Nutrients

Although phosphorous and nitrogen are essential to the health and proper functioning of aquatic ecosystems, excessive amounts of these nutrients can stimulate the growth of nuisance levels of algae, which can in turn interfere with the beneficial uses of streams and rivers. In excess amounts, algae can produce unpleasant tastes and odors in drinking water, taint the taste of fish flesh, produce allergic reactions in humans, clog and corrode water supply and irrigation systems and equipment, alter the composition of macroinvertebrate and fish communities, and interfere with aesthetic and recreational uses of rivers and streams (Nordin 1985). Despite the potentially detrimental effects of nutrient-induced algal growth and the obvious need for regulatory guidelines, no enrichment-specific water quality criteria have been established for phosphorous and nitrogen. Currently, the only nutrient standards that exist at the federal level are designed to protect drinking water from toxic levels of nitrate, and are inadequate for preventing eutrophication of lakes and rivers. EPA has directed the states to develop nutrient criteria and Montana is in the process of developing such standards (Suplee pers. com).

The only nutrient standards that have been adopted in Montana at the time of completion of this thesis are for the Clark Fork River in western Montana (see **Table 7**). These nutrient limits are designed to prevent the growth of nuisance levels of attached algae (Tri-State Implementation Council 1998; Watson et al., 1999).

The EPA has provided guidelines to the states for the development of nutrient standards, and has recommended nutrient criteria for each eco-region of the US (EPA 2000). Criteria for nutrients in the Western Forested Mountains (Eco-region II) include refined Level III subregions within Montana. The two most applicable Level III ecoregions for the Boulder River Watershed are ecoregion 16 (Montana Valley and Foothill Prairies), which would apply in the Boulder downstream of Natural Bridge, and ecoregion 15 (Northern Rocky Mountains) which would apply in the Boulder upstream of Natural Bridge. Nutrient criteria were established based on the 25th percentile of nutrient concentrations in the population of all streams in a region for which nutrient data were available. The EPA criteria (summarized in **Table 8**) have not been adopted by the state of Montana, and their suitability to the Boulder River is not currently known. The Clark Fork River is in ecoregion 16, and its standards and targets are similar to the criteria proposed for this ecoregion, lending some validation to the national criteria.

Total Phosphorous (TP)

In this study, 75% of sampled TP concentrations fell below the upper Clark Fork standard of 20 ug/l, and all samples fell below the lower Clark Fork standard of 40 ug/l. However, most samples exceeded EPA's Region 15 and 16 targets (**Figure** 7). Boulder River TP concentrations exhibited little between-site variability and provided no evidence of significant human-caused phosphorous sources in the Boulder upstream of Natural Bridge and Hass Ranch (site 11). Between site 2 (Box Canyon Ranger Station) and site 10 (Aller Ranch), an area that encompassed the suspected nutrient sources in the upper Boulder, median TP concentrations varied little. Median total phosphorous was 11 ug/l at site Box Canyon (2), rose slightly to 12.5 ug/l at Hicks Park Campground (3) and then returned to 11 ug/l at Flemming Bridge (4), Aspen Campground (6), Clydehurst (7), and Falls Creek (8). Median TP declined slightly to 10 ug/l at Whispering Pines (9) and then rose to 12 ug/l at site Aller Ranch (10). In the River below Natural Bridge, median TP was 11 ug/l at all sites except at the mouth of the Boulder (14), where it was 13 ug/l. This variability is probably within the error of the analytical test.

Nitrate+Nitrite Nitrogen

Nitrate+nitrite levels in the river **(Figure 8)** were not well characterized above Hicks Park (site 3). Some of the highest median nitrate levels were observed at Hicks Park Campground (3) and Flemming Bridge (4), both upstream of the most concentrated development on the upper Boulder (developed sites include 6-10). The range of nitrate+nitrite concentrations was also wider and the maximum concentrations higher at these sites than in the more developed areas of the upper Boulder. These findings suggest that human-caused sources were not measurably elevating nitrate+nitrite concentrations in the upper river during the study period. However, only a detailed groundwater study could sort out whether potential sources are having an impact. Median nitrate+nitrite concentrations increased only slightly in the lower river, except below the confluence of with the West Boulder (site 13), where the median concentration increased 35 ug/l. With the exception of 3 sites (3, 4, and 13), 75% of the samples from all sites were below EPA's nitrate/nitrite criteria for Region 16. However, 50% or more of the samples at 4 sites exceeded the criteria for Region 15, and many other sites had a substantial number of samples that exceeded the Region 15 criteria. Since nutrients are often higher in groundwater than in surface water, low surface water levels during the study period probably resulted in higher than typical nitrate levels in the river.

Total Nitrogen (TN)

Because nitrate+nitrite concentrations were very low, the TN values reported here are almost entirely the results of TKN concentrations. Median total nitrogen (TN) levels (**Figure 9**) showed more variability than TP or nitrates. At the sampling sites in the most heavily developed portions of the upper Boulder—Clydehurst (7), Falls Creek (8), and Whispering Pines (9), TN concentrations were not markedly elevated above concentrations in the less developed, upstream portions of the river. Median TN concentrations in the Boulder below Natural Bridge were lowest at Hass Ranch (10 ug/l) and increased slightly downstream, reaching a maximum of 288 ug/l at the sampling site near the mouth of the Boulder (14). The median values at most sites were below Region 16 criteria but above Region 15 criteria.

Chlorophyll a

Heavy growth of attached algae can rapidly deplete available nutrients, so low concentrations of nutrients in the water column do not necessarily indicate that a water body is free of eutrophication. Hence, the standing crop of attached algae (as measured by chlorophyll a levels) is often used as an indicator of excessive nutrient enrichment. As is the case with nutrients, there are currently no national or statewide standards for acceptable levels of attached chlorophyll a. The standards for the Clark Fork River are based in part on the work of Richard Nordin, of British Columbia's Water Quality Unit, who reviewed the commonly used methods of measuring algae productivity in streams and rivers and concluded that attached algae biomass as estimated by the amount of chlorophyll a per square meter of stream bottom was the most accurate and technically feasible method (Nordin 1985). Based on a literature review, Nordin estimated the level of algal biomass in a stream or river likely to impair beneficial uses. He concluded that to protect recreational and aesthetic uses in streams and rivers of British Columbia, chlorophyll a should not exceed 50 mg/m^2, and that to protect aquatic life from adverse changes, chlorophyll a should not exceed 100 mg/m^2 (Nordin 1985). The Clark Fork standards are also based on the work of Eugene Welch, who determined that at chlorophyll a levels greater than 100-150 mg/m^2, nuisance levels (coverage exceeding 20%) of filamentous algae are likely to occur, and significant changes in the aquatic community are likely to result (Welch et al., 1987). Based upon Welch and Nordin's conclusions, the maximum acceptable level of chlorophyll a in the Clark Fork River was set at 100 mg/m^2 as a summer mean and 150 mg/m^2 as a maximum at any one sampling time (Tri-State Implementation Council 1996). These nuisance prevention criteria are believed to be applicable to a wide range of rocky bottomed rivers in Montana, including the Boulder River (Watson, pers.com.).

Chlorophyll a samples were collected on three occasions during the course of this study. The first was in August of 1999 to document late-summer concentrations. The second and third occasions were in June of 2000 and 2001 to document the extent of the *Ulothrix zonata* bloom that occurred in the Boulder on these occasions. Late summer chlorophyll a samples were collected at the original seven sampling locations that were initially established in 1999 for the DEQ beneficial use determination assessment. June *Ulothrix* sampling was limited to the river above Natural Bridge because this is the area of the visible *Ulothrix* growth.

Late summer (August 1999) chlorophyll a levels in the Boulder River were far below the Clark Fork standard at all sites sampled (**Figure 10**). Algal levels ranged from a low of 4.2 mg/m^2 at Basin Creek (1) to a high of 22 mg/m^2 at the site below the confluence with the East Boulder (12). In the river above Natural Bridge, where excessive algae growth was common in the early 1990's (Levine 1996), late summer 2000 chlorophyll a concentrations did not exceed 6.1 mg/m^2. These low chlorophyll a concentrations may be due to the fact that the highest flow (9940 cfs) ever recorded at the USGS Boulder River gauging station near Big Timber occurred three years previously, on 6/5/97. By scouring and dislodging the rocks upon which algae grows, this flood flow could have reduced algae density to an unusually low level from which the algae (and hence chlorophyll a levels) had not yet had time to recover.

Although samples of late-summer chlorophyll a were taken only once, in August 1999, a visual algae inspection was conducted during each water quality sampling visit, including the late summer periods of 2000 and 2001. Based on these visual inspections, the August 1999 chlorophyll a concentrations approximately reflect the maximum late summer algae levels observed in 2000 and 2001.

Attached algae is usually sampled for standard compliance in mid – late summer because that is when high levels are most likely to interfere with beneficial uses like recreation, irrigation, or support of aquatic life. The timing of peak levels varies depending on the type of algae and the year-to-year pattern of flows in the stream (Watson, pers.com, Dodds 1991). The only visually noticeable filamentous algae observed during the study period occurred early to mid-June in 2000 and 2001 in the river above Natural Bridge. Samples of these algae were collected in June 2000 and sent to Loren Bahls, PhD. of Hannea for analysis. Dr. Bahls identified the algae as *Ulothrix zonata*.

Although samples were taken for chlorophyll a analysis in June of 2000 and 2001, the 2000 samples were inadvertently destroyed by the lab; hence the only results available are from 2001. Nevertheless, the sampling locations and the levels of *U. zonata* growth were essentially the same in both years, so these results should be approximately representative of algal density in 2000 as well as 2001. Samples were intentionally collected from the areas of heaviest growth to document maximum concentrations.

Chlorophyll a concentrations during the *Ulothrix* bloom (**Figure 11**) were highly variable, ranging from a low of 36 mg/m^2 at Clydehurst (7) to a maximum of 135 mg/m^2 at Flemming Bridge (4). At all sites, except Clydehurst (7), chlorophyll a levels from the *Ulothrix* bloom exceeded the 50 mg/m^2 identified by Nordin (1985) as being protective of recreational and aesthetic uses. Only at Flemming Bridge (4) did the chlorophyll a level exceed the 100 mg/m^2 mean summer chlorophyll standard identified as being protective against changes in aquatic life. No Boulder station exceeded the Clark Fork peak chlorophyll standard of 150 mg/m^2.

Although *Ulothrix* was sampled at only 7 sites, this alga was observed throughout the reach upstream of Aller Ranch (site 10), with the exception of the Hillary Bridge area (between sites 3 and 4). The algae's absence from the Hillary Bridge area probably results from the relatively small gravel substrate in this part of the river, which is more easily dislodged by high flows, thus scouring the rocks of algae and precluding the development of noticeable filaments. Elsewhere in the Boulder River, *Ulothrix* was observed growing on small cobbles and larger rocks in areas of shallow (< 2 ft), slow flowing water. In most places, this apparent combination of habitat requirements limits *Ulothrix* to the areas along the stream banks and to shallow riffle areas. Deep and/or fast flowing water appears to preclude the growth of *Ulothrix*. As a result, the algae typically occupies only a small fraction of the stream area. However, in places where larger areas of suitable habitat exist, and particularly where exposure to the sun is high, *Ulothrix* can form large mats in the upper Boulder. Because *Ulothrix* growth takes place during the falling limb of the spring hydrograph, falling water levels leave the algae exposed on dry rocks, thus limiting its growth to a period of approximately two weeks in most areas in June of 2000 and 2001.

Other Water Chemistry

Water quality samples were analyzed for 21 metals. Results are presented in **Appendix B**. In general, concentrations of total recoverable metals were below state water quality standards at all sampling sites. Twelve of the 22 metals were below detection at all sites. Most of the other metals were present at concentrations only slightly above detection and still below water quality standards. However, the concentration of total recoverable aluminum at Sites 12 (Below East Boulder) and 13 (Below West Boulder) was 200 ug/l, and at site 14 (near the mouth) it was 100 ug/l. The chronic aquatic life standard for aluminum is 87 ug/l dissolved aluminum. Although it is impossible to know for certain what fraction of the total recoverable aluminum found in this study is dissolved, it is likely to be quite low. A large fraction of total aluminum found in Montana streams is typically in the particulate form, and thus the levels of soluble Al at sites 12-14 are not likely to be of concern (Brick, pers. com.). Additionally, there is no known source of human-caused aluminum upstream of Site 12, which suggests that aluminum levels in the Boulder are the result of natural processes. Second, the concentration of total recoverable iron at Sites 12, 13, and 14 was 0.28, 0.16, and 0.11 mg/l respectively. Although these levels are well below those that could be harmful to human or aquatic life, they are approaching 0.3 mg/l total recoverable iron, the concentration at which iron can start to interfere with aesthetic properties such as taste, odor, and staining (MDEQ 1999).

Metals in Fine Bed-Sediment

Concentrations of metals in the fine sediments (<0.062 mm) of the Boulder River were below levels considered harmful (**Appendix C**). While no standards currently exist in Montana for metals in sediment, the Washington State Department of Ecology has released preliminary values that can be used for comparison (WSDE 1997). Levels of metals in all sediment samples collected from the Boulder River were below the Washington State standards. Of potential interest, however, is the copper concentration of 65 mg/kg at Site 1 (Basin Creek). The concentration dropped to 7 mg/kg at Aspen Campground (6), and is no higher than 13 mg/kg at any of the other sites (**Figure 12**). Historic mining in the vicinity of Basin Creek could account for this possibly elevated concentration. However, even at the Basin Creek site, the concentration of copper was well below the proposed Washington State standard of 390 mg/kg. Because only one sample was taken at each site, no estimate of variability is possible; hence it is not possible to say for certain whether the values measured at each site differ significantly.

Macroinvertebrate Habitat Assessment and Community Composition Assessment

The macroinvertebrate portion of this study consisted of two parts: first, an assessment of the macroinvertebrate habitat conditions at each site, and second, an assessment of the species composition of the macroinvertebrate community itself.

Macroinvertebrate Habitat Assessment

Macroinvertebrate habitat assessment enhances the interpretation of macroinvertebrate data (Barbour and Stribling 1991). If health of the macroinvertebrate community appears more damaged than the habitat quality would predict, then water pollution might be suspected as a cause of impairment (Bollman 2000). Macroinvertebrate habitat assessment was conducted according to standard DEQ methods (described in methods) that result in a numeric score for each location that is based on the percent of the maximum score possible (based on a reference site or ecoregion composite).

Macroinvertebrate habitat assessment results are summarized in **Tables 9** and **10** and **Figure 13** (Bollman 2000). Macroinvertebrate habitat was rated as optimal at the three locations in the upper Boulder above Natural Bridge — Basin Creek (1), Aspen Campground (6) and Aller Ranch (10), received scores of 98, 96 and 88 percent of maximum, respectively. Macroinvertebrate habitat was also optimal at three of the four sites in the lower river below Natural Bridge. At Hass Ranch (11) and near the mouth (14), macroinvertebrate habitat received a score of 82.5 and at site 3 it was 88. Only at Hass Ranch (11) was the macroinvertebrate habitat rated as sub-optimal, receiving a score of 76.5. At this site, streambanks were moderately unstable and riparian vegetation had been impacted by grazing.

Macroinvertebrate Community Assessment

As explained in methods, the macroinvertebrate community of the Boulder River was assessed using six standard DEQ metrics that result in a numeric score for each site that is based on the percent of the maximum score possible. Results are summarized in **Figure 14** and **Table 11**.

In the upper river above Natural Bridge, the three sites sampled supported macroinvertebrate communities that indicated excellent water quality and full support of beneficial uses. Below Natural Bridge, Hass Ranch (11) and the site near the mouth (14), sampled macroinvertebrate communities indicated "full support" of beneficial uses despite evidence of "slight impairment". At the sites below the East Boulder (12) and below the West Boulder (13), sampled macroinvertebrate communities indicated only partial support of beneficial uses and slight water quality impairment (Bollman 2000).

Periphyton

Algae are present in all streams, and, as primary producers, are directly affected by physical and chemical factors such as temperature, nutrients, and toxins; thus algae community composition provides a useful indication of the biological integrity of streams and rivers (Bahls 2000).

In general, periphyton samples collected from the Boulder River (summarized in **Table 12**) indicated good to excellent biologic integrity, little or no impairment, and full support of beneficial uses.

The periphyton community was evaluated based on a suite of nine metrics, which, unlike the macroinvertebrate metrics discussed above, are not combined into a single score for each site, but are instead evaluated individually. At five of the seven sites sampled, all nine indices indicated full support of beneficial uses. At the other two sites, Basin Creek (1) and Hass Ranch (11), eight of the nine indices indicated full support, while the ninth, percent abnormal cells, indicated moderate impairment and partial support of beneficial uses. The abnormal cells at Basin Creek (1) may have been caused by low-level toxicity from metals released by historic mining in the area. The cause of the abnormal cells at Hass Ranch (11) is unknown and may be natural in origin (Bahls 2000).

Stream Reach Assessment

The stream channel and riparian habitat of the Boulder River above Natural Bridge were scored as being in generally excellent condition, with scores ranging from 91% to 95% of potential (**Figure 15, Table 13**). Riparian vegetation is mostly intact, growing and reproducing vigorously, except for relatively infrequent breaks where development has taken place. The channel itself is well-armored by rock, and, with a few exceptions, appears largely stable. The Boulder is able to access its floodplain, except where naturally confined by the often narrow valley.

Below the Natural Bridge, the valley widens and is dominated by agricultural uses. These uses, while not incompatible with stream and riparian health, do take an inevitable toll on the land, which is reflected in the somewhat lower health assessment scores for the lower river. Scores in the lower river were 81 at Hass Ranch (11), below the West Boulder (13), and near the mouth of the Boulder (14). At the site below the East Boulder (12), the score was 78. In general terms, the lower river is characterized by more frequent breaks in the riparian vegetation, less regeneration of woody riparian vegetation, and more severe bank instability, as reflected by the occasional presence of riprap, actively eroding banks, and instream sediment. The degree to which these changes are natural vs. human-caused is difficult to determine with a qualitative, visual assessment of this sort, but given pervasive alteration of the Boulder and its floodplain in the lower river, it seems likely that a significant portion results from human activity.

It should be emphasized that although no stream segment scored lower than 75 (a score lower than 75 indicates impairment), the four reaches in the lower river scored only a few points higher (78 - 82), thus narrowly escaping impairment classification. Overall, the channel and riparian habitat of the lower Boulder are probably best characterized as non-impaired, but threatened, and should be watched carefully for signs of further degradation.

CONCLUSIONS

Is the Boulder impaired by nutrients and algae?

Based on the data collected in this study, it does not appear that the growth of the filamentous green algae *Ulothrix zonata* is controlled by anthropogenic nutrient enrichment to the Boulder River. First, nutrient concentrations in the river above Natural Bridge where *Ulothrix zonata* was found show no obvious correlations with development in the watershed. Concentrations of both nitrogen and phosphorous are in fact higher in the relatively undisturbed portions of the river than they are in developed areas. Second, *Ulothrix zonata* growth, as measured by chlorophyll a concentrations, appears to be uncorrelated with both development and nutrient concentrations. In general, *Ulothrix zonata* appears to thrive throughout the upper Boulder regardless of nutrient concentrations so long as suitable habitat of cobble substrate, shallow and gently flowing water, and exposure to direct sunlight, is present.

The scientific literature on *Ulothrix zonata* lends credence to the idea that the algae can grow in profuse blooms in low nutrient settings without anthropogenic nutrient inputs. Welch et al., (1998) noted that dense mats of *Ulothrix* have been found to occur in spring in oligotrophic streams where they are not expected, a situation that appears to be analogous to the Boulder. In a study comparing streams in old growth and clearcut areas of a forest, Bilby and Bisson (1992) found dense springtime blooms of *Ulothrix sp.* in nitrogen-limited clearcut area streams, despite a low average nitrate+nitrite concentration of 9 ug/l over two years of monthly sampling. Very little green algae was found in the old growth stream in spite of a significantly higher mean nitrate+nitrite concentration of 22 ug/l, suggesting that the increase in solar radiation as a result of canopy removal in the clearcut areas was largely responsible for the increase in green algae. Although it is possible that the lower nitrate+nitrite concentrations in the clearcut area streams were the result of uptake by algae, monthly sampling combined with a short-lived algal bloom make this scenario unlikely. *Ulothrix* blooms began in spring and were gone by early June. Otherwise both locations were dominated by diatoms. Likens et al. (1970) found that increases in nitrate were detectable even when accompanied by a *Ulothrix* bloom in a clearcut watershed, but relative sizes of the streams studied by Likens et al and Bilby and Bisson may make comparisons questionable. Jourdonnais and Stanford (1985) found that *Ulothrix* growth in the littoral zone of Flathead Lake Montana was uncorrelated with groundwater contamination from shoreline drainfields. Similarly, *Ulothrix* growth in the upper Boulder appears to be uncorrelated with the presence of septic systems in developed areas.

One way of deciding if the upper Boulder is impaired by filamentous algae is to consider the question without reference to the *Ulothrix zonata* blooms in June. Doing so reveals that the nutrient levels in the upper Boulder are generally below Clark Fork nutrient standards. Although Boulder nutrient concentrations did frequently exceed EPA region 15 and 16 guidelines, the suitability of these guidelines to the Boulder River is currently unknown. Assuming the Clark Fork standards are the most applicable to the Boulder, nutrient levels in the Boulder River generally appeared to be below levels thought to be capable of supporting nuisance levels of algae. In addition, Boulder nutrient levels generally decline from the upstream sites through the developed areas, suggesting that human-caused sources are not increasing nutrient concentrations noticeably. Late-summer chlorophyll a concentrations are also below Clark Fork standards. Macroinvertebrate and periphytyon analysis are indicative of a clean mountain river, with no evidence of human-caused nutrient enrichment. Thus, without the *Ulothrix zonata* June blooms, the Boulder River above Natural Bridge showed no evidence of impairment by algae in 1999 - 2001.

If one now considers the reaches with *Ulothrix* blooms, little changes. Although June chlorophyll a levels were higher than in August, they were below the Clark Fork River summer maximum standard, and *Ulothrix* growth is generally limited to a small portion of the stream channel for a relatively brief period of approximately two weeks. Because *Ulothrix* samples from the Boulder were deliberately taken from the areas of most concentrated growth, while the Clark Fork standards apply to samples that are collected randomly at one depth in the wadeable stream channel, Boulder River chlorophyll a levels probably fall below the Clark Fork standards by an even wider margin than reported here.

Boulder nutrient levels are below Clark Fork standards and are apparently uncorrelated with development and uncorrelated with *Ulothrix* levels. The scientific literature indicates that *Ulothrix zonata* grows profusely in spring in streams where nutrient levels are far lower than in the Boulder. Thus it appears likely that the growth of *Ulothrix* in the Boulder is controlled by natural processes, and that beneficial uses were not impaired by excess nutrients and algae in 1999 – 2000 in the upper Boulder, despite the *Ulothrix* blooms.

Is the Boulder supporting its beneficial uses?

As of 2001, the Boulder River appeared to be fully supporting all of its beneficial uses. According to Montana DEQ's rules for determining use support (available: http://www.amsa-cleanwater.org/advocacy/wqmar/montanameth.pdf), for aquatic life to be fully supported, no more than one data category (physical/habitat, biological, and chemical) can indicate moderate impairment; or no more than one biological assemblage (periphyton and macroinvertebrates) can indicate moderate impairment. Impairment classification for all parameters sampled in the DEQ stream assessment at the 7 stations is summarized in **Table 14**. Only macroinvertebrates (at stations 5 and 6) indicate less than full support of beneficial uses. All other data categories indicate full support, placing the Boulder in the fully supporting category. Although nutrient levels exceeded EPA Region 15 and 16 draft criteria, the suitability of these criteria to Montana streams has not been evaluated. It is assumed here that the Clark Fork standards are the most relevant to the Boulder River at the time of this report.

Impairment classifications for each parameter were determined as follows:

Macroinvertebrates: Macroinvertebrate community analysis indicated partial support of aquatic life at sites 5 and 6, and full support at all other sites.

Periphyton: Analysis of attached algae communities indicates full support of aquatic life at all sites.

Chlorophyll a: In late summer when high algal are most likely to cause water quality problems, chlorophyll a levels in the Boulder did not exceed 22 mg/m^2, well below levels that constitute a nuisance or are considered harmful to aquatic life support. Spring chlorophyll concentrations from *Ulothrix zonata* in the river above Natural Bridge are somewhat higher, but there is no evidence that these concentrations are unnatural, and they are below the Clark Fork chlorophyll a standard.

Nutrients: Boulder total phosphorous levels were below the Clark Fork standard at all sites. Median total nitrogen concentrations exceed the Clark Fork standard at several sites in the upper Boulder. However, these sites are upstream of most of the development on the Boulder, and total nitrogen concentrations generally declined in a downstream direction; hence it appears likely that total nitrogen levels are natural, and do not reflect human-caused nutrient impairment. Nitrate + nitrite concentrations, which are a better measure of bioavailable nitrogen, are also higher at the upstream sampling stations, again suggesting that human-caused sources of nitrogen do not impair the Boulder River. Although Boulder nutrient concentrations frequently exceeded draft EPA region 15 and 16 criteria, these criteria may not be appropriate to the Boulder River and appear to be unrealistically low given that they were exceeded even in the undeveloped portions of the upper Boulder River surrounded by designated wilderness.

Metals in sediment: Metals in Boulder sediment were measured below Washington State standards set to protect aquatic life (Newby, pers. com.)

Other water chemistry: No violations of state water quality standards were found. Metals in the water column were below Montana water quality standards.

Dewatering: The irrigation diversion structures that were the reason the Boulder was placed on the 2000 303(d) list have been removed according to the Montana Fish, Wildlife and Parks (Mike Poore, pers. com.).

RECOMMENDATIONS

Although the Boulder River currently appears to support its beneficial uses, the river also appears to be nearing thresholds at which further impact could undermine water quality in the basin. Fortunately, the Sweet Grass Conservation District has worked with local residents and the DEQ to establish a Boulder River Watershed Group to address existing water quality problems and to prevent new threats to water quality from arising. The primary goal of the group is to develop a water quality restoration plan that can be used for long-term management planning in the Boulder River watershed. This plan entails identifying areas in need of improvement, and developing mitigation measures and management strategies that would ultimately meet the long-term water quality goals of the group (Mathieus pers. com.).

The group has received funding from the state for two preliminary studies to identify major impacts throughout the Boulder River Watershed, and help landowners propose and prioritize future improvement projects. The first study aims to understand more fully the extent and impacts of noxious weed infestations, stream bank erosion, residential development, stream bank stabilization measures, and in-channel infrastructure (irrigation, stream crossings, etc.), and to identify opportunities for improving/maintaining stream channel stability and riparian plant community health. The second is an irrigation efficiency study, the primary goal of which is to identify inefficiencies in irrigation systems throughout the watershed (Mathieus pers. com.). The Montana Department of Fish, Wildlife and Parks has estimated minimum flows needed to protect the fishery and has reserved a water right to this minimum flow (Williams pers. com).

In addition to these studies, it is recommended that the group visually monitor algal levels. If algal levels seem to increase noticeably, or there is a 10% increase in septic systems in the watershed, then nutrient and chlorophyll a monitoring should be resumed, especially at key sites above Natural Bridge. Nutrient monitoring should be conducted quarterly at a minimum for nitrate/nitrite nitrogen, total nitrogen, and total phosphorous. Although soluble phosphorous was not monitored in this study, it should be included in future monitoring efforts if possible to help identify potential sources of human-caused nutrients. Chlorophyll a monitoring should also accompany nutrient monitoring, and sampling should be conducted twice annually, once in late summer and once in June during the period of *Ulothrix zonata* growth. Samples should not be composited so as to give an estimate of variability, allowing a statistical evaluation of significant increased in algal levels. In order to minimize the costs of sampling, a smaller number of sampling stations than used in this study could be monitored. Critical sites include above Box Canyon Range Station (site 2) as a measure of reference conditions; Aspen Campground (site 6), above the most concentrated development in the upper Boulder; Whispering Pines (site 9), an area of relatively heavy development; Hass Ranch (site 11) the uppermost site in the river below Natural Bridge; and near the river mouth (site 14) as a measure of cumulative impacts and loading to the Yellowstone River.

Given the current protection this area enjoys, the most likely threats to water quality are over grazing in the riparian zone and increased stream-side development. Given that the nutrient levels observed in the river have supported higher levels of algae elsewhere, protection of stream-side vegetation that provides shade to the stream should be a priority. Obviously, protecting stream-side vegetation provides multiple benefits besides reducing the chance of unacceptable increases in algae levels. In addition, maintaining the natural flow regime is critical to maintaining high quality habitat and to avoiding increases in algal levels.

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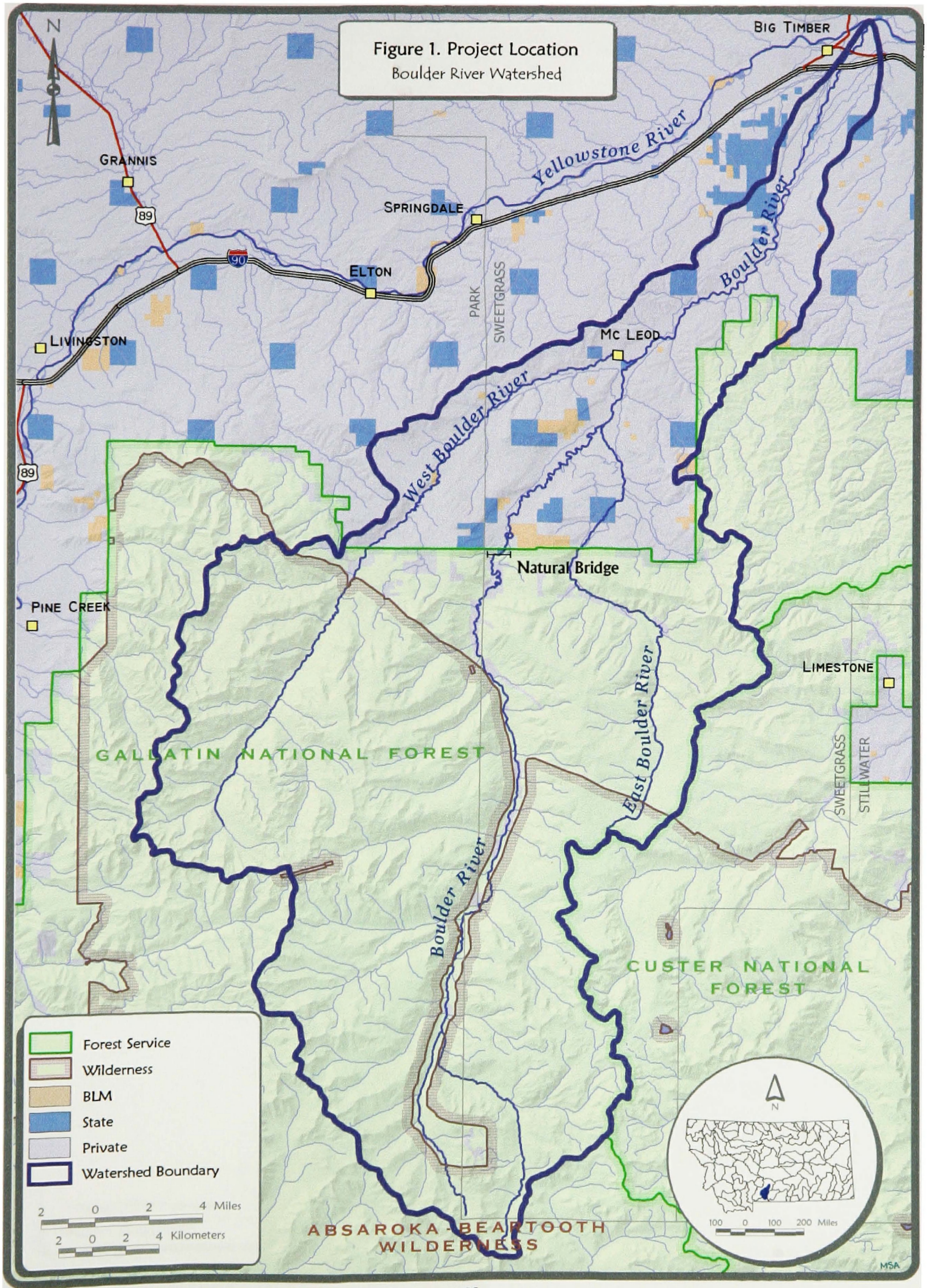

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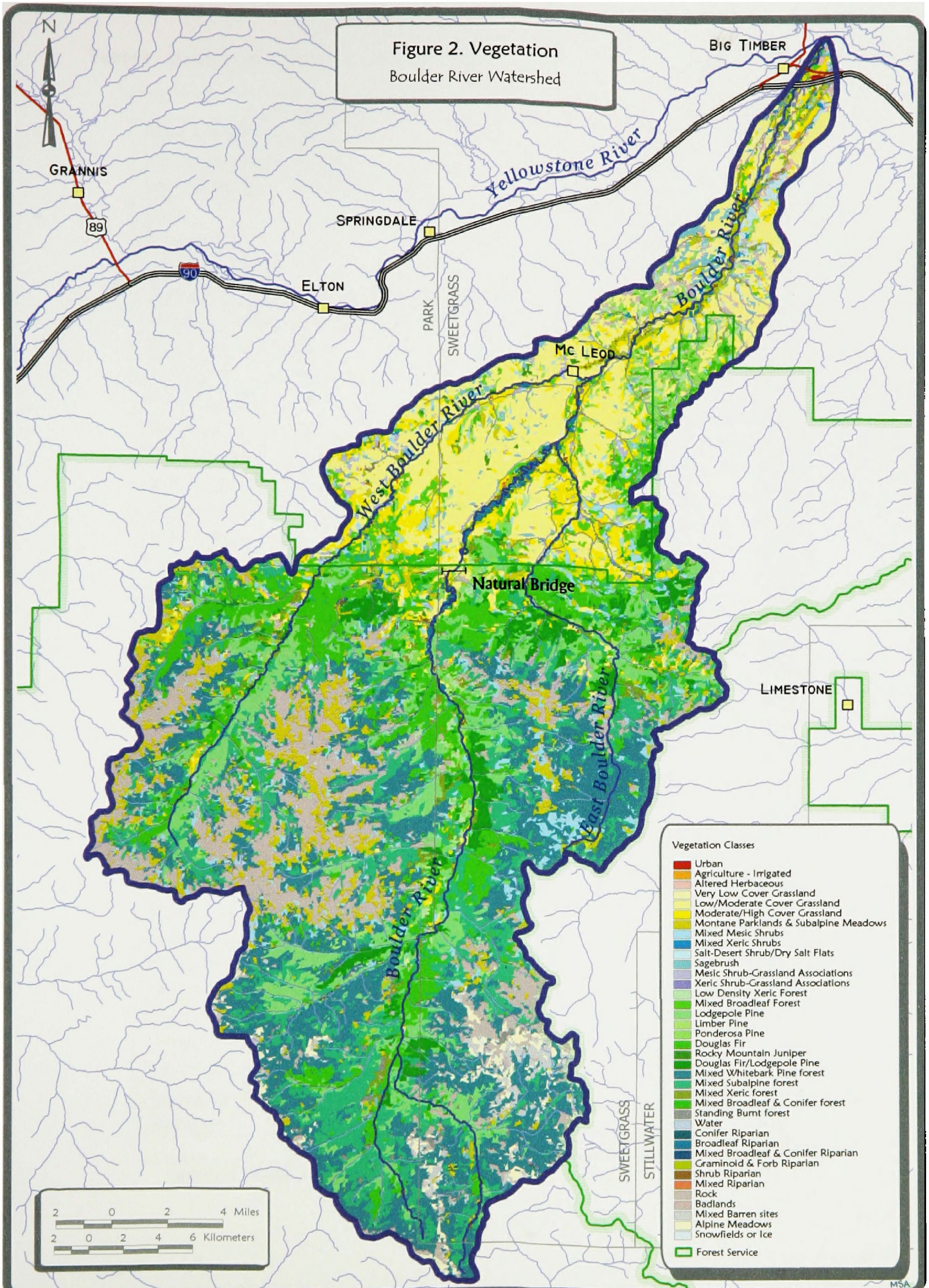


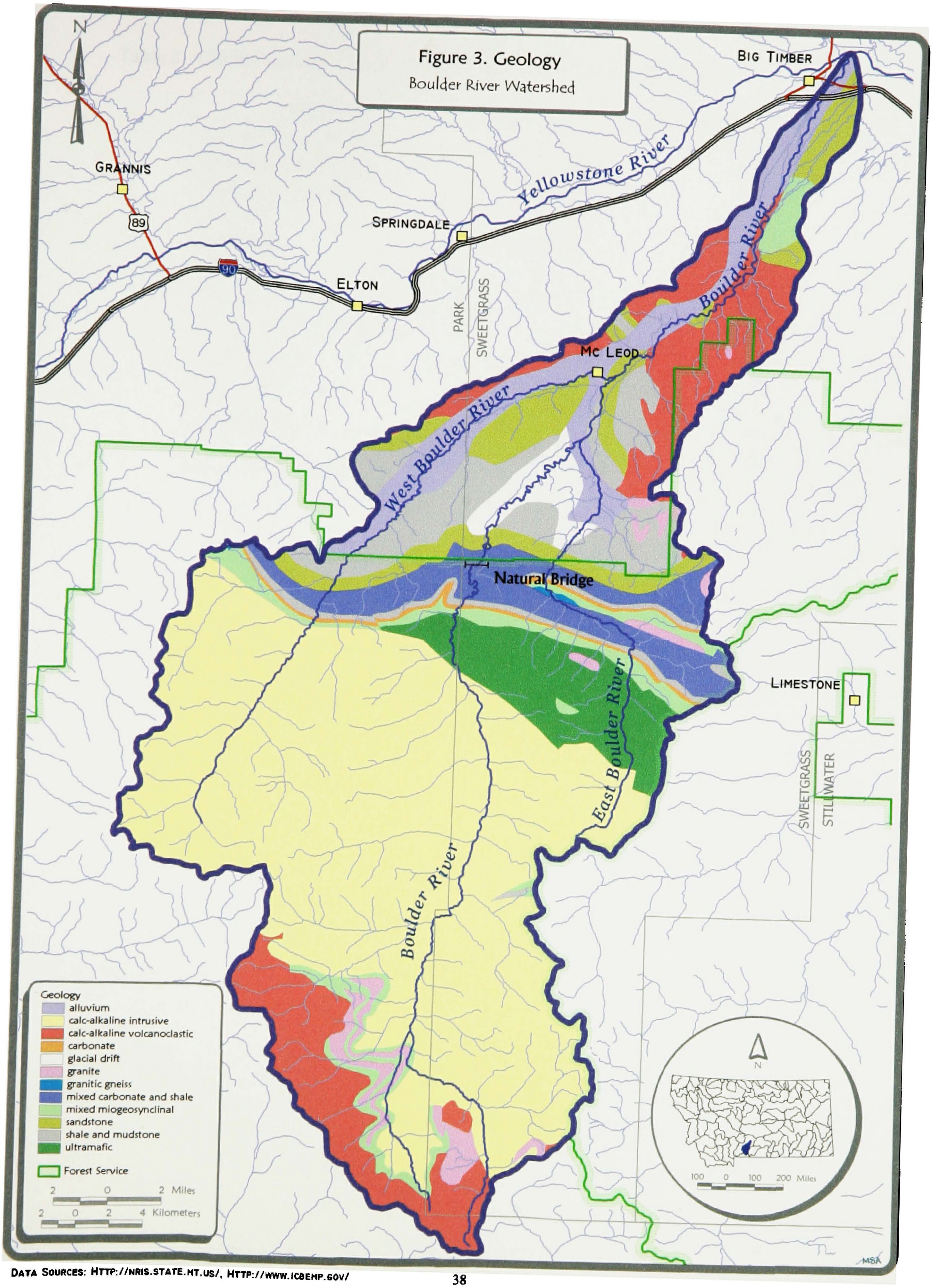
Figure 2. Vegetation
Boulder River Watershed

Data Source: http://nris.state.mt.us/

Table 1. Boulder Watershed Vegetation Types

Vegetation Type	Acres	% of Area
Mixed Whitebark Pine Forest	59,455	17.60
Mixed Subalpine Forest	42,603	12.61
Low/Moderate Cover Grasslands	38,170	11.30
Rock	36,228	10.72
Douglas-fir	31,299	9.26
Lodgepole Pine	30,520	9.03
Montane Parklands and Subalpine Meadows	15,264	4.52
Moderate/High Cover Grasslands	12,744	3.77
Mixed Mesic Shrubs	10,716	3.17
Douglas-fir/Lodgepole Pine	10,505	3.11
Ponderosa Pine	6,466	1.91
Graminoid and Forb Riparian	5,859	1.73
Mixed Broadleaf Forest	5,173	1.53
Low Density Xeric Forest	4,085	1.21
Alpine Meadows	3,784	1.12
Mixed Xeric Forest	3,605	1.07
Sagebrush	3,305	0.98
Mixed Barren Sites	2,959	0.88
Broadleaf Riparian	2,588	0.77
Limber Pine	1,962	0.58
Shrub Riparian	1,611	0.48
Mesic Shrub-Grassland Associations	1,454	0.43
Standing Burnt Forest	1,163	0.34
Salt-Desert Shrub/Dry Salt Flats	1,159	0.34
Water	834	0.25
Very Low Cover Grasslands	786	0.23
Altered Herbaceous	772	0.23
Mixed Broadleaf and Conifer Forest	752	0.22
Mixed Riparian	462	0.14
Mixed Xeric Shrubs	347	0.10
Xeric Shrub-Grassland Associations	316	0.09
Rocky Mountain Juniper	295	0.09
Mixed Broadleaf and Conifer Riparian	161	0.05
Conifer Riparian	155	0.05
Urban or Developed Lands	151	0.04
Snowfields or Ice	143	0.04
Agricultural Lands - Irrigated	38	0.01
Badlands	8	0.00
TOTAL	**337,900**	**100.00**

(Source: NRIS 2003)



Data Sources: Http://nris.state.mt.us/, Http://www.icbemp.gov/

Table 2. USGS Geologic Mapping Units in the Boulder River Watershed

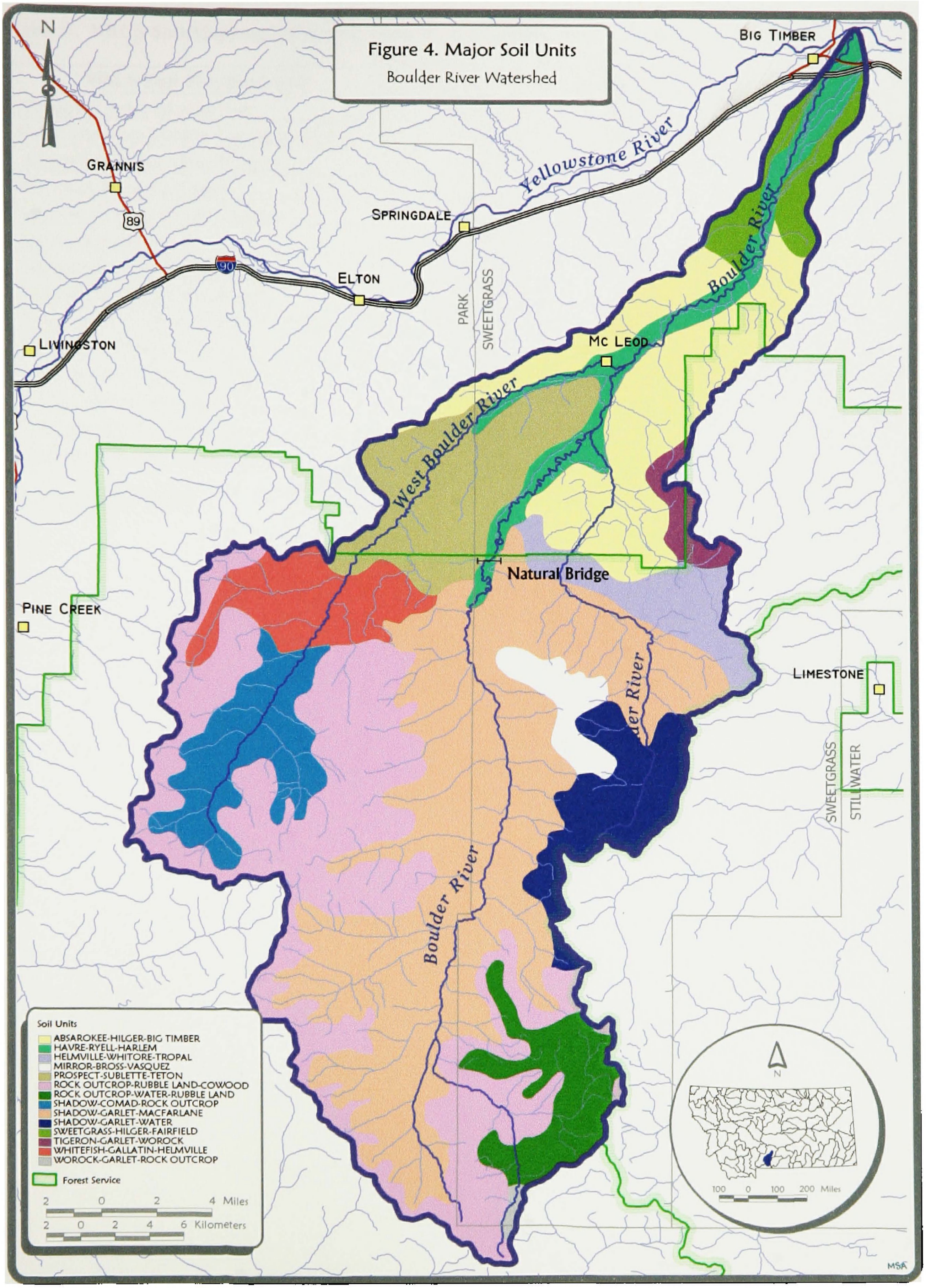
Lithology	Acres	% of Total Area
calc-alkaline intrusive	159,384	47.17
calc-alkaline volcanoclastic	42,640	12.62
shale and mudstone	24,899	7.37
alluvium	21,031	6.22
sandstone	20,700	6.13
ultramafic	19,675	5.82
mixed carbonate and shale	18,751	5.55
mixed miogeosynclinal	14,809	4.38
granite	7,394	2.19
glacial drift	5,625	1.66
carbonate	2,727	0.81
granitic gneiss	263	0.08
TOTAL	**337,898**	**100.00**

(Source: NRIS 2003)

Table 3. USGS Geologic Mapping Unit Definitions

USGS Geologic Mapping Unit	Definition
Alluvium	Unconsolidated sediment (clay, silt, sand, gravel). Includes glacial outwash deposits.
Calc-alkaline intrusive rocks	Calc-alkaline suite of intrusive rocks. Generally granodiorite to diorite.
Calc-alkaline volcanoclastic rocks	Calc-alkaline suite of pyroclastic rocks and volcanic flows. Generally andesite to quartz-latite.
Carbonate	Sedimentary rock, mostly composed of limestone and dolomite, locally metamorphosed to marble.
Glacial drift	Material deposited by glacial processes. Includes till and moraine (unstratified) as well as outwash (stratified).
Granite	Includes intrusive rhyolitic rocks
Granitic gneiss	Dominantly granitic gneiss, migmatite, augen gneiss, and hornblende gneiss.
Mixed carbonate and shale	Mixed sequences of carbonate rock and shale with subordinate sandstone and conglomerate
Mixed miogeosynclinal	Mixed sequences of miogeosynclinal sedimentary rocks. Includes interlayered shale, siltstone, lithic sandstone, quartzite, and conglomerate.
Sandstone	Medium-grained detrital sedimentary rock derived from sand
Shale and mudstone	Fine-grained sedimentary rock derived from clay
Ultramafic	Includes associated gabbroic rocks

Source: http://geo-nsdi.er.usgs.gov/metadata/open-file/95-680/metadata.faq.html

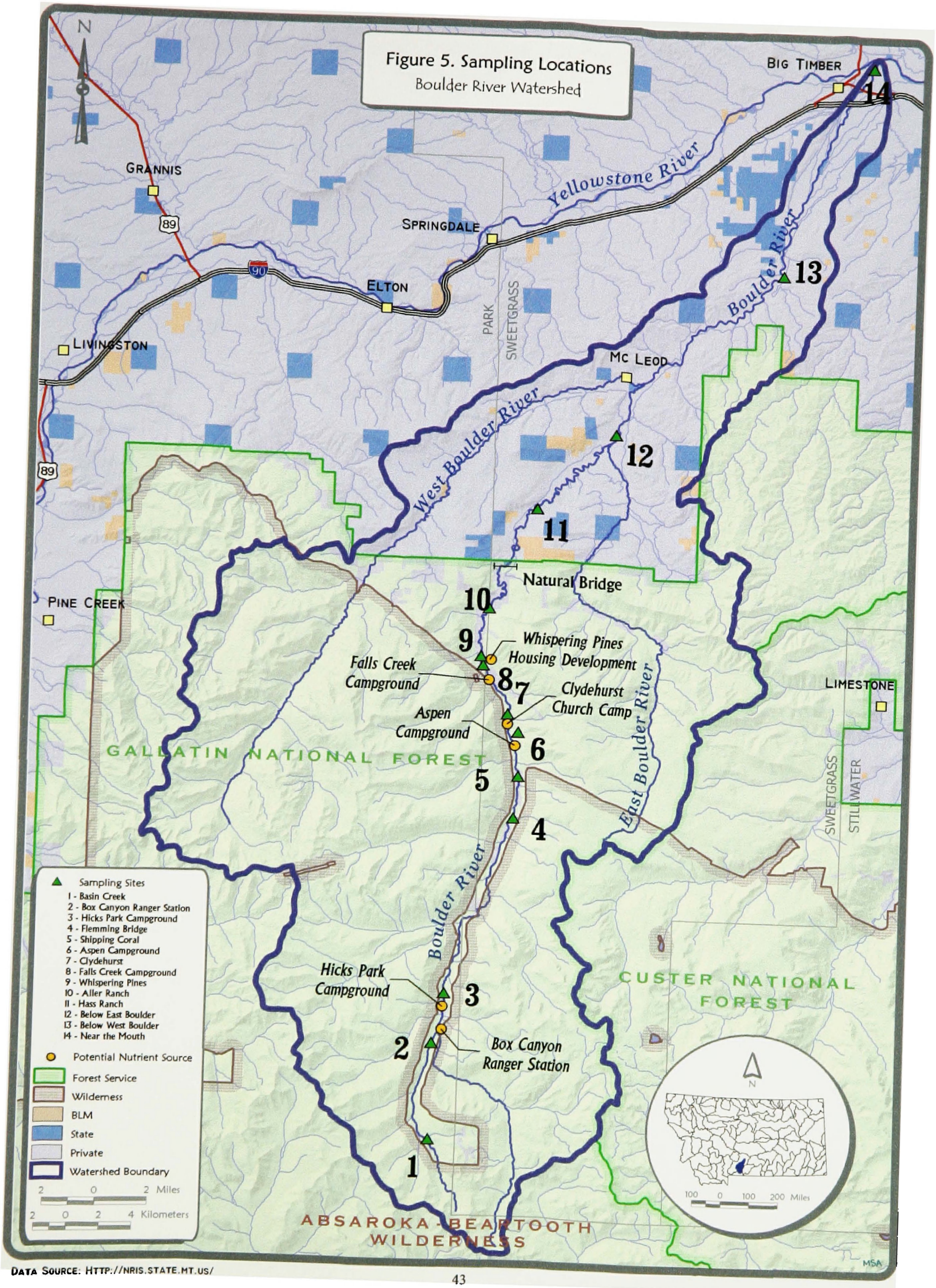


Data Source: http://nris.state.mt.us/

Table 4. NRCS Soil Mapping Units in the Boulder River Watershed

NRCS Soil Mapping Unit	Acres	% of Area
Shadow-Garlet-Macfarlane	95,069	28.1
Rock Outcrop-Rubble Land-Cowood	72,627	21.5
Absarokee-Hilger-Big Timber	37,687	11.2
Prospect-Sublette-Teton	25,645	7.6
Shadow-Comad-Rock Outcrop	17,013	5.0
Havre-Ryell-Harlem	16,489	4.9
Shadow-Garlet-Water	15,079	4.5
Whitefish-Gallatin-Helmville	14,539	4.3
Rock Outcrop-Water-Rubble Land	13,541	4.0
Helmville-Whitore-Tropal	11,329	3.4
Sweetgrass-Hilger-Fairfield	8,254	2.4
Mirror-Bross-Vasquez	5,861	1.7
Tigeron-Garlet-Worock	4,032	1.2
Worock-Garlet-Rock Outcrop	733	0.2
TOTAL	**337,898**	**100.0**

(Source: NRIS 2003)



Data Source: http://nris.state.mt.us/

Table 5. Sampling Locations on the Boulder River, August 1999 to October 2001

Location	Site #	Description	Miles from Mouth	Lat.	Long.
Below Basin Creek*	1	Headwaters site; sampled only once in August 1999	62	45 13 00	110 14 59
Box Canyon Ranger Station	2	Uppermost site with feasible frequent access; above all major development	57.3	45 16 20	110 15 00
Hicks Park Campground	3	Downstream of pit toilet in USFS campground	56	45 18 04	110 14 30
Flemming Bridge	4	Upstream of most development	46	45 24 12	110 11 32
Shipping Corral	5	Site of noticeable *Ulothrix* growth; sampled for *Ulothrix* only	44	45 25 39	110 11 22
Aspen Campground*	6	Downstream of USFS campground	42.5	45 27 11	110 11 27
Clydehurst Church Camp	7	Downstream of Clydehurst church camp	41	45 27 48	110 11 59
Falls Creek Campground	8	Downstream of USFS campground	39	45 29 28	110 13 14
Whispering Pines Development	9	Downstream of housing development	37.5	45 29 47	110 13 21
Aller Ranch*	10	End of major anthropogenic sources above Natural Bridge	36	45 31 28	110 13 03
Hass Ranch*	11	First access below Natural Bridge	20.5	45 34 59	110 10 57
Below East Boulder*	12	Below Boulder/East Boulder Confluence	22.5	45 37 43	110 07 20
Below West Boulder*	13	10 yards upstream of 8 mile bridge	11	45 43 24	110 13 14
Near the Mouth*	14	¼ mile upstream of the confluence with the Yellowstone River	1	45 50 48	109 55 37

*Included in the August 1999 beneficial use support determination stream assessment

Figure 6. Monthly Discharge of the Boulder River at Big Timber, 1999, 2000, 2001 and Mean Monthly Discharge 1948-2001 in Cubic Feet per Second (cfs).

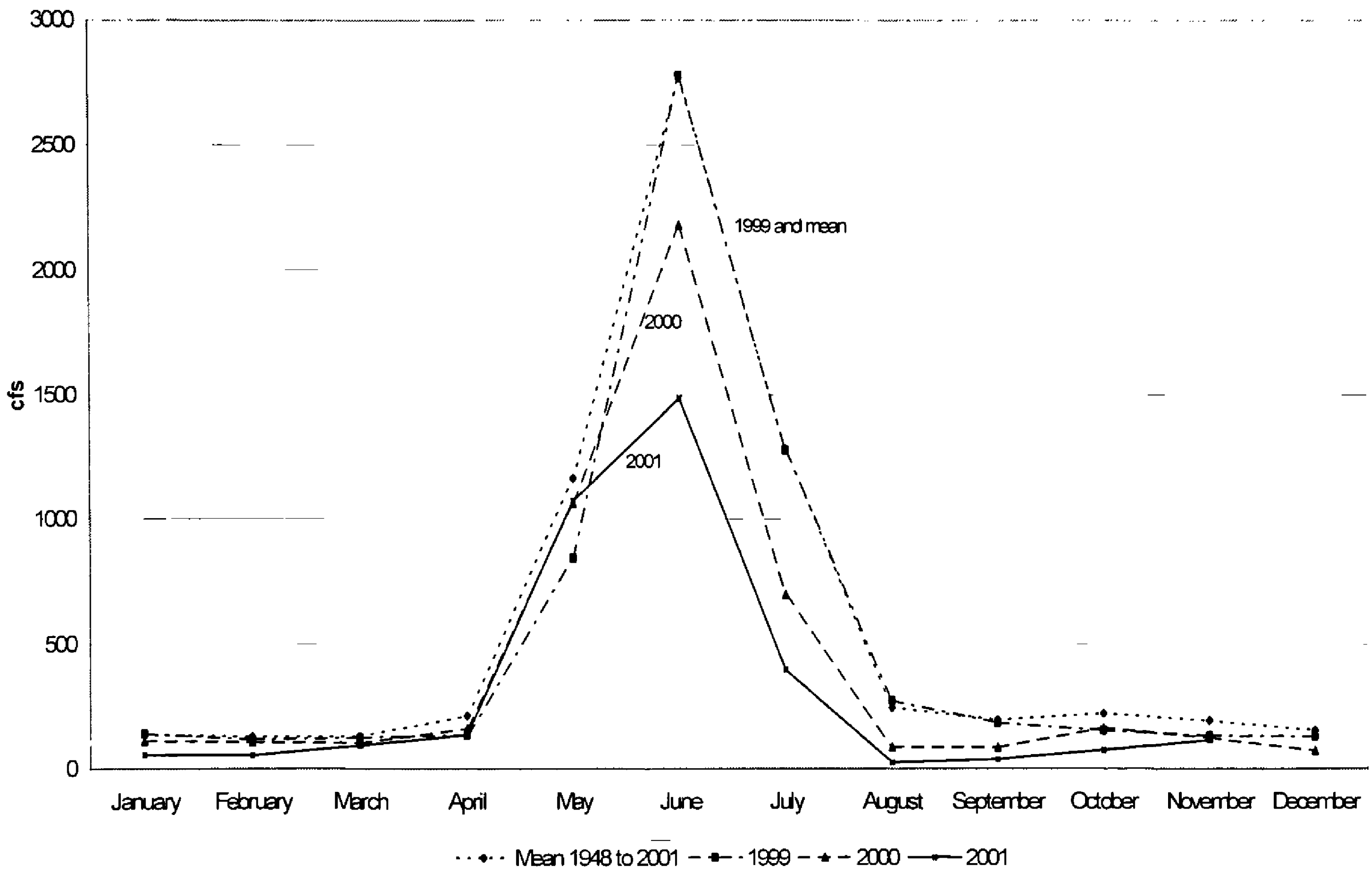


Table 6. Boulder River streamflow at Big Timber on Dates of Water Sampling for Nutrients, August 1999-October 2001.

Date of sampling	Streamflow (cfs) on date of sampling	% of average flow on this date	Average streamflow (cfs) on this day, 1948 - 2001
8/13/99	473	207%	229
5/1/00	297	76%	390
6/3/00	2,040	85%	2,386
7/15/00	582	46%	1,267
8/4/00	108	30%	362
9/20/00	68	31%	217
10/21/00	154	69%	222
12/9/00	80	51%	158
1/20/01	50	38%	133
2/27/01	75	60%	125
3/18/01	89	67%	132
4/14/01	94	53%	177
5/18/01	1,050	91%	1,156
6/29/01	1,250	51%	2,443
7/31/01	52	11%	453
8/26/01	18	9%	198
10/20/01	104	46%	224

Table 7. Clark Fork River Nutrient and Benthic Chlorophyll Standards and Targets (Tri-State Implementation Council 1998).

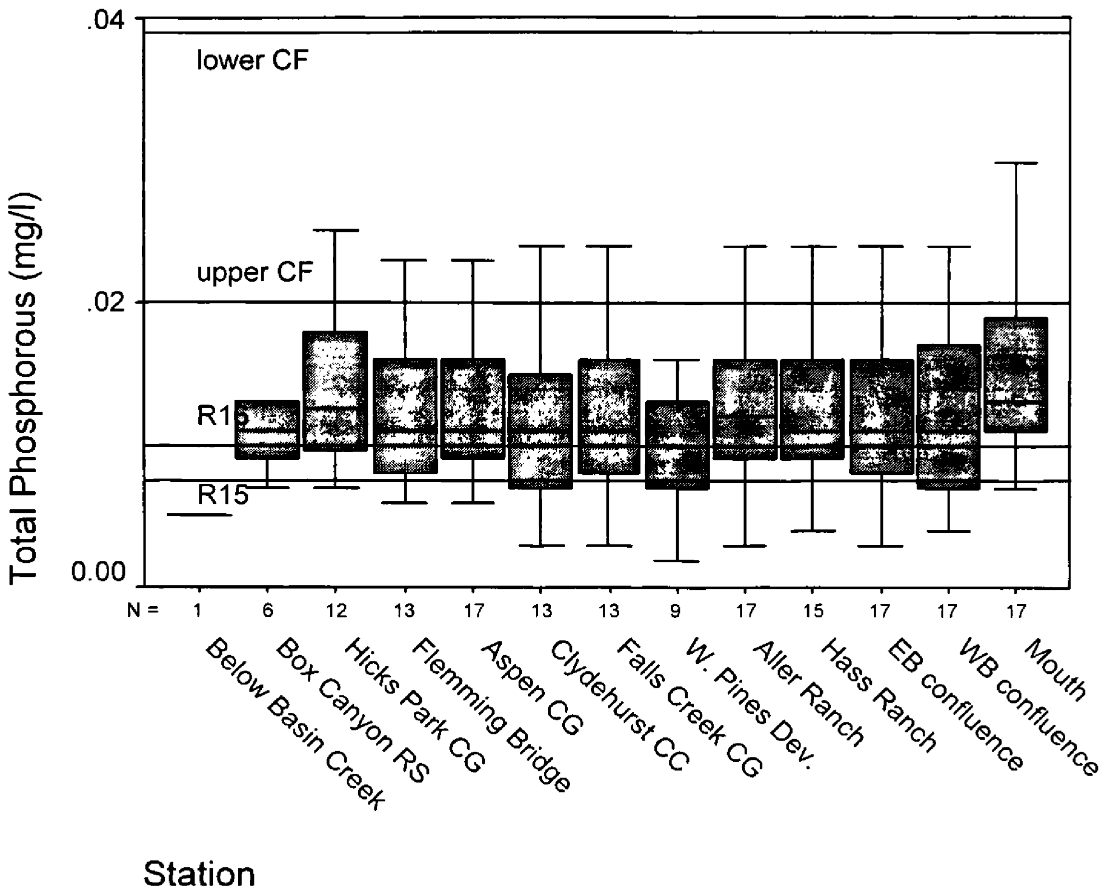
Parameter	Standard or Target
Benthic chlorophyll a	100 mg/m^2 (summer mean) 150 mg/m^2 (summer max)
Total nitrogen	300 ug/l
Total phosphorous	20, 39 ug/l[1]
Soluble inorganic N (target)	30 ug/l
Soluble reactive phosphorous (target)	6 ug/l

Table 8. U.S. EPA Nutrient Criteria for Level III Ecoregions 16 and 15 (US EPA 2000)

Parameter	Number of Streams	Reported Values		Target (25^{th} Percentiles)
		Min	Max	
Region 16: Montana Valley and Foothill Prairies				
NO_2+NO_3 (ug/l)	36	20	1760	60
TN (ug/l)-calculated	NA	70	2940	250
TP (ug/l)	51	3.25	370	10
Region 15: Northern Rockies				
NO_2+NO_3 (ug/l)	133	<10	2910	20
TN (ug/l)-calculated	NA	<100	3830	100
TP (ug/l)	150	<1	760	7.75

Note: The minimum values for Region 15 were all reported as zero—but detection limits were reported here, which is more accurate.

Figure 7. Boulder River Total Phosphorous Concentrations, August 1999 – October 2001

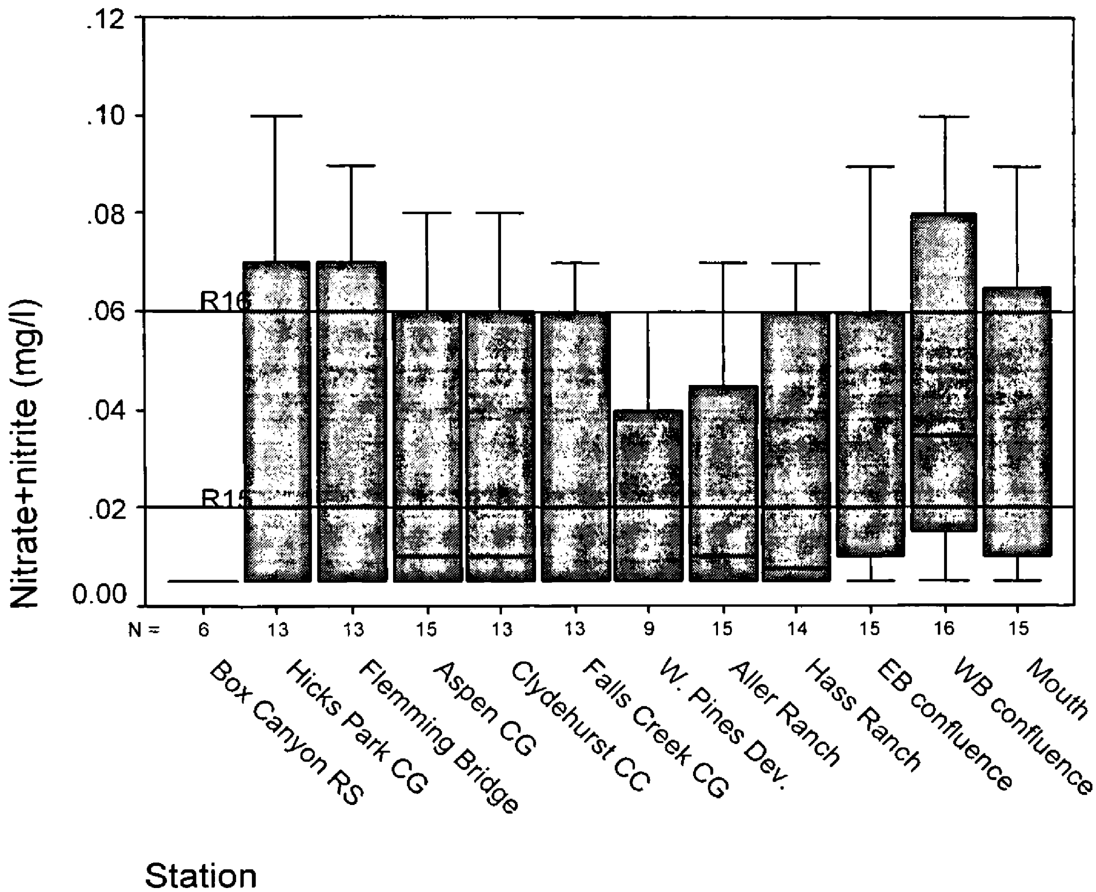


The shapes of the boxplots are based on median, quartile, and extreme values of the data. The box encloses the interquartile range, which contains 50% of the values. The median is displayed as the centerline of the box. The top and bottom whiskers display the maximum and minimum observed values, excluding outliers and extreme values.

R16 and R15 represent the EPA's draft Region 15 and 16 nutrient criteria, and upper CF and lower CF represent the Clark Fork River standards for the river above and below its confluence with the Blackfoot River.

CG=Campground
RS=Ranger Station
CC=Church camp

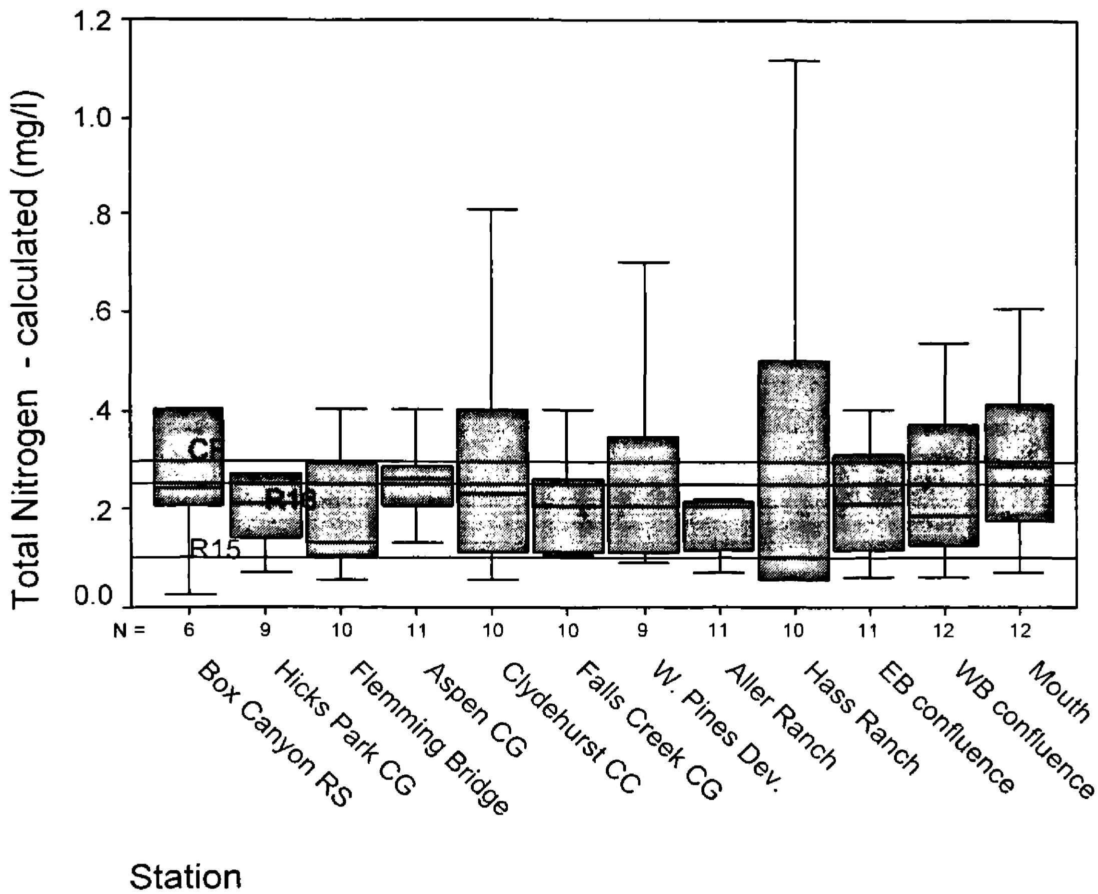
Figure 8. Boulder River nitrate+nitrite concentrations, August 1999 – October 2001.



Box plots are explained in Figure 7. Many of the samples were below the detection limit of 10 ug/l; hence the median lines for several sites were set at ½ the detection limit (5 ug/l).

R16 and R15 represent the EPA's draft Region 15 and 16 nutrient guidelines.

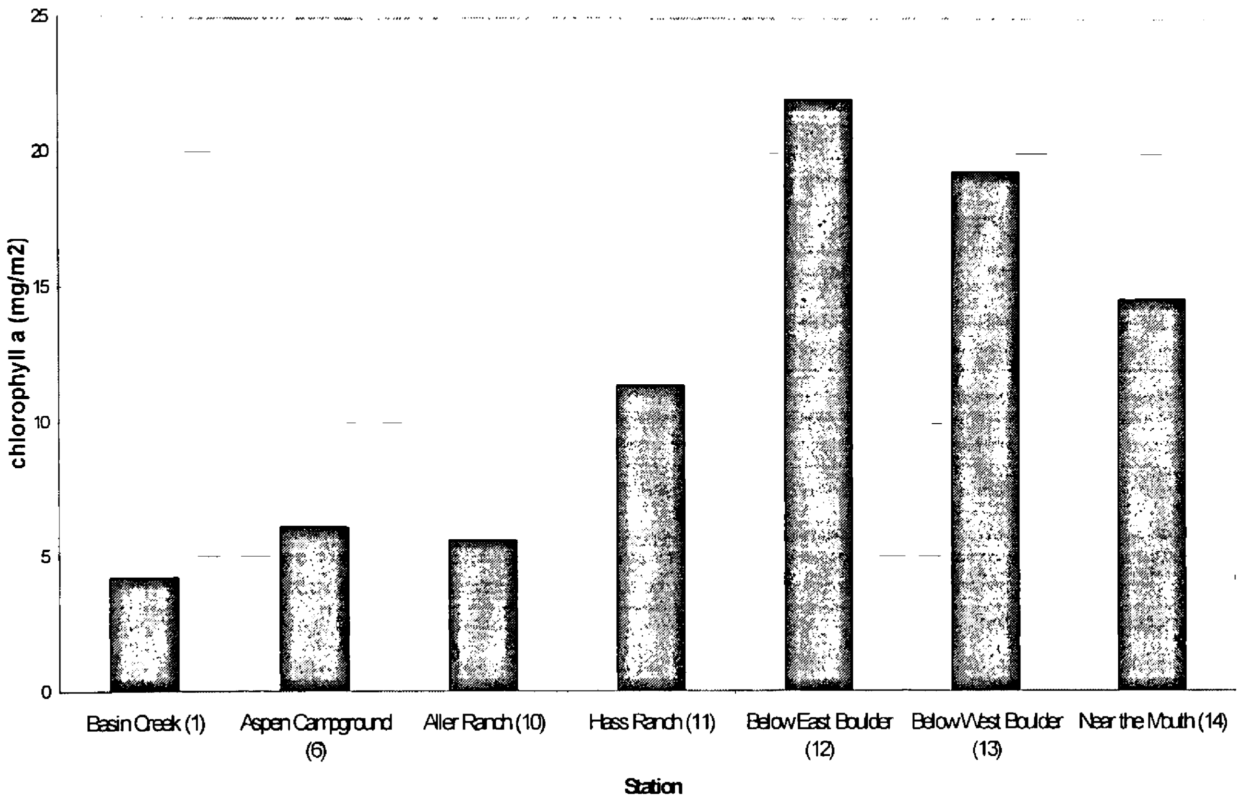
Figure 9. Boulder River total nitrogen concentrations, August 1999 – October 2001.



Box plots are as described in Figure 7.

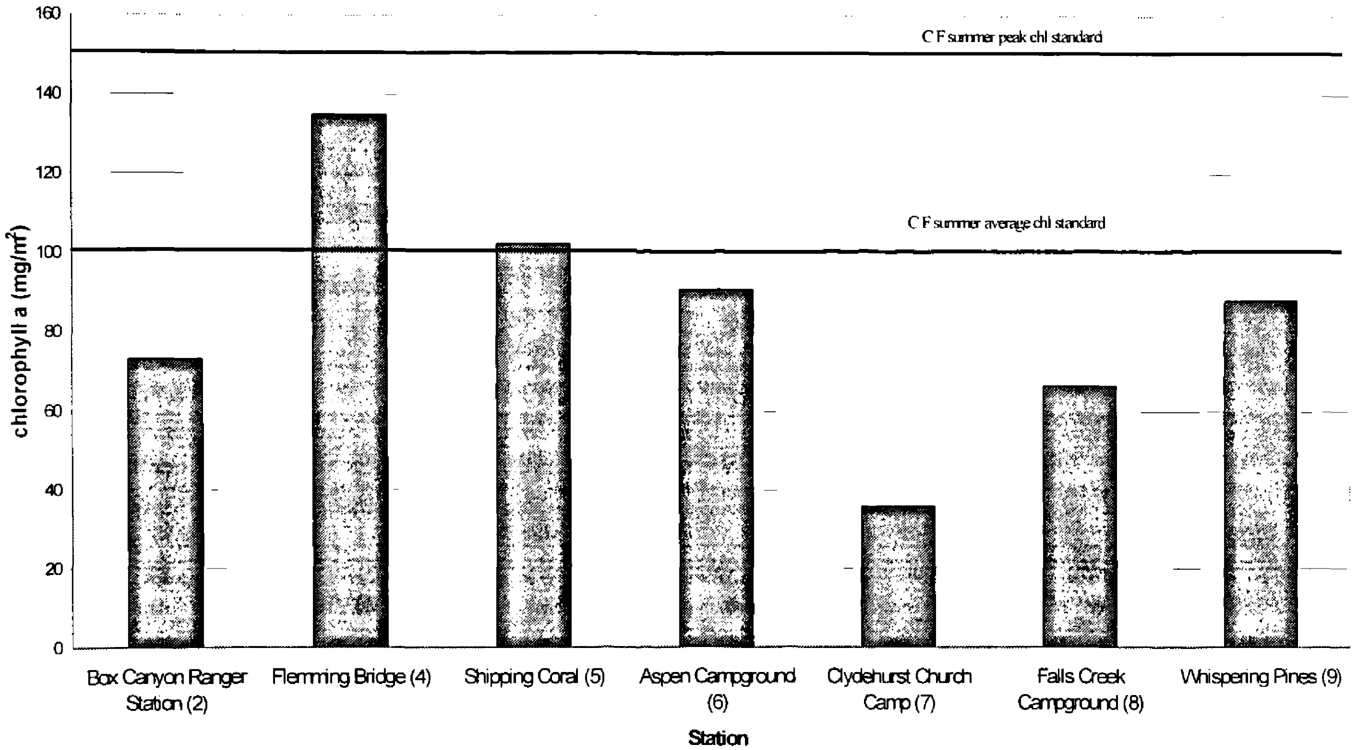
R16 and R15 represent the EPA's draft Region 15 and 16 nutrient guidelines. CF represents the Clark Fork Standard.

Figure 10. Boulder River attached algae standing crop, August 1999



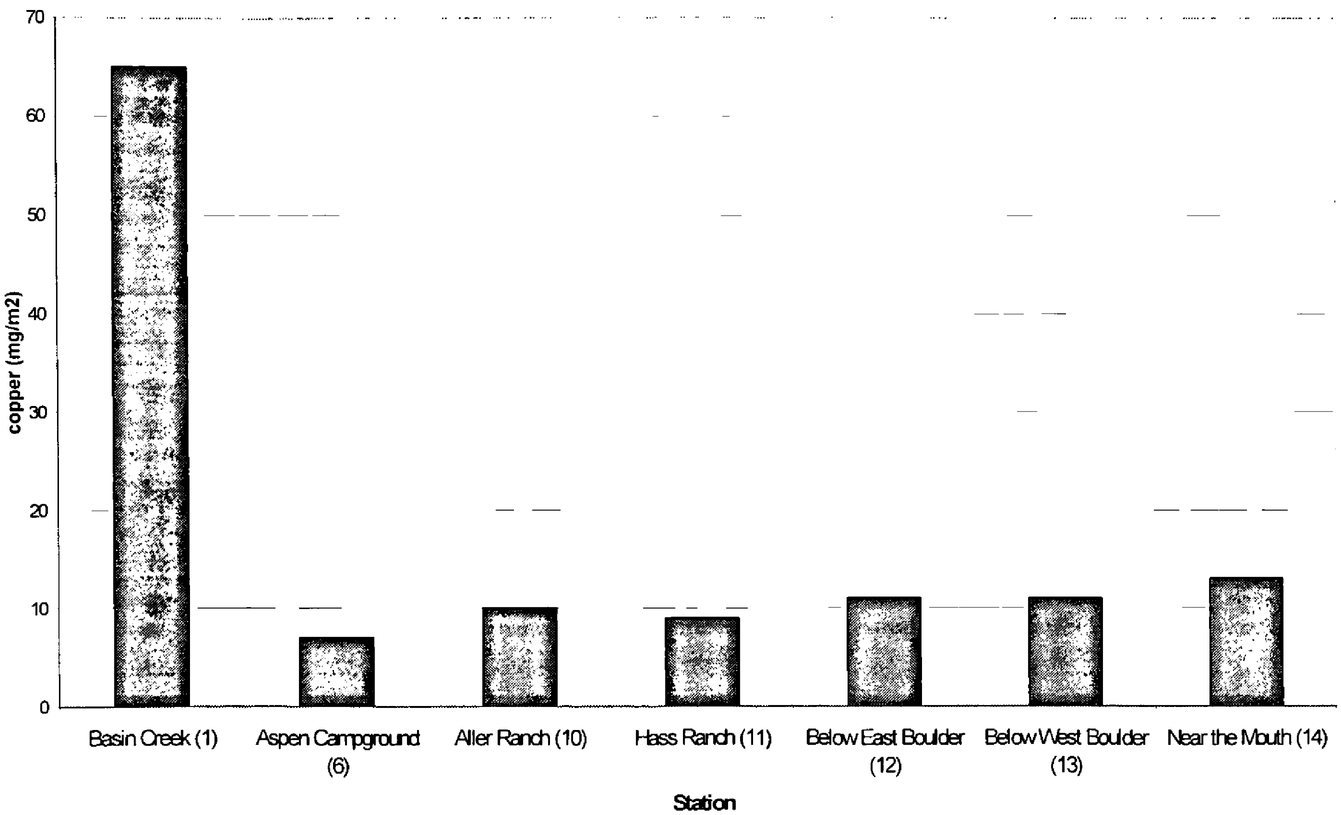
Values are based on a single composite sample from each site made by combining 15 replicate samples colleted by random sampling over an area 100 m^2.

Figure 11. Boulder River maximum attached algae standing crop, June 2001. (note: samples were collected in areas with heaviest accumulations of *Ulothrix zonata*)



Values are based on a single composite sample from each site made by combining 15 replicate samples collected by sampling in the heaviest areas of growth.

Figure 12. Copper Concentrations in Boulder River Fine Bed Sediments, August 1999



Values are based on a single composite sample from each site made by combining 5 replicate samples collected from depositional areas at each sampling site.

Table 9. Macroinvertebrate Habitat Assessment of sites dominated by Riffles/Runs, Boulder River, August 1999. (Bollman 2000)

Max Possible Score	Parameter	Basin Creek (1)	Aspen Campground (6)	Below East Boulder (12)	8 Mile Bridge (13)	Near the Mouth (14)
10	Riffle Development	10	10	10	10	10
10	Benthic Substrate	10	10	10	7	10
20	Embeddedness	18	20	18	20	18
20	Channel Alteration	20	20	18	18	19
20	Sediment Deposition	20	18	14	20	16
20	Channel Flow Status	19	18	18	18	12
20	Bank Stability	10/10	10/10	8/8	10/10	9/9
20	Bank Vegetation	10/10	10/9	7/7	7/7	8/7
20	Vegetated Zone	10/10	10/8	7/7	6/6	7/7
160	**Total**	157	153	132	139	132
	Percent of Maximum	98	96	82.5	87	82.5
	CONDITION*	**OPTIMAL**	**OPTIMAL**	**OPTIMAL**	**OPTIMAL**	**OPTIMAL**

Condition categories: Optimal >80 of maximum score; Sub-optimal 75-56%; Marginal 49-29%; Poor <23%.

Table 10. Macroinvertebrate Habitat Assessment of sites dominated by Pools/Glides, Boulder River, August 1999. (Bollman 2000)

Maximum Possible Score	Parameter	Aller Ranch (10)	Hass Ranch (11)
20	Benthic Substrate	15	18
20	Pool Substrate	18	18
20	Pool Variability	20	18
20	Channel Alteration	20	14
20	Sediment Deposition	20	18
20	Channel Sinuosity	10	15
20	Channel Flow Status	20	18
20	Bank Vegetation	10/10	7/7
20	Bank Stability	9/9	5/5
20	Vegetated Zone	9/6	5/5
200	**Total**	179	153
	Percent of Maximum	88	76.5
	CONDITION*	**OPTIMAL**	**SUB-OPTIMAL**

Condition categories: Optimal >80 of maximum score; Sub-optimal 75-56%; Marginal 49-29%; Poor <23%.

Figure 13. Boulder River Macroinvertebrate Habitat Assessment Scores, August 1999. (Bollman 2000)
(Scores are percent of maximum possible based on a composite reference for the ecoregion)

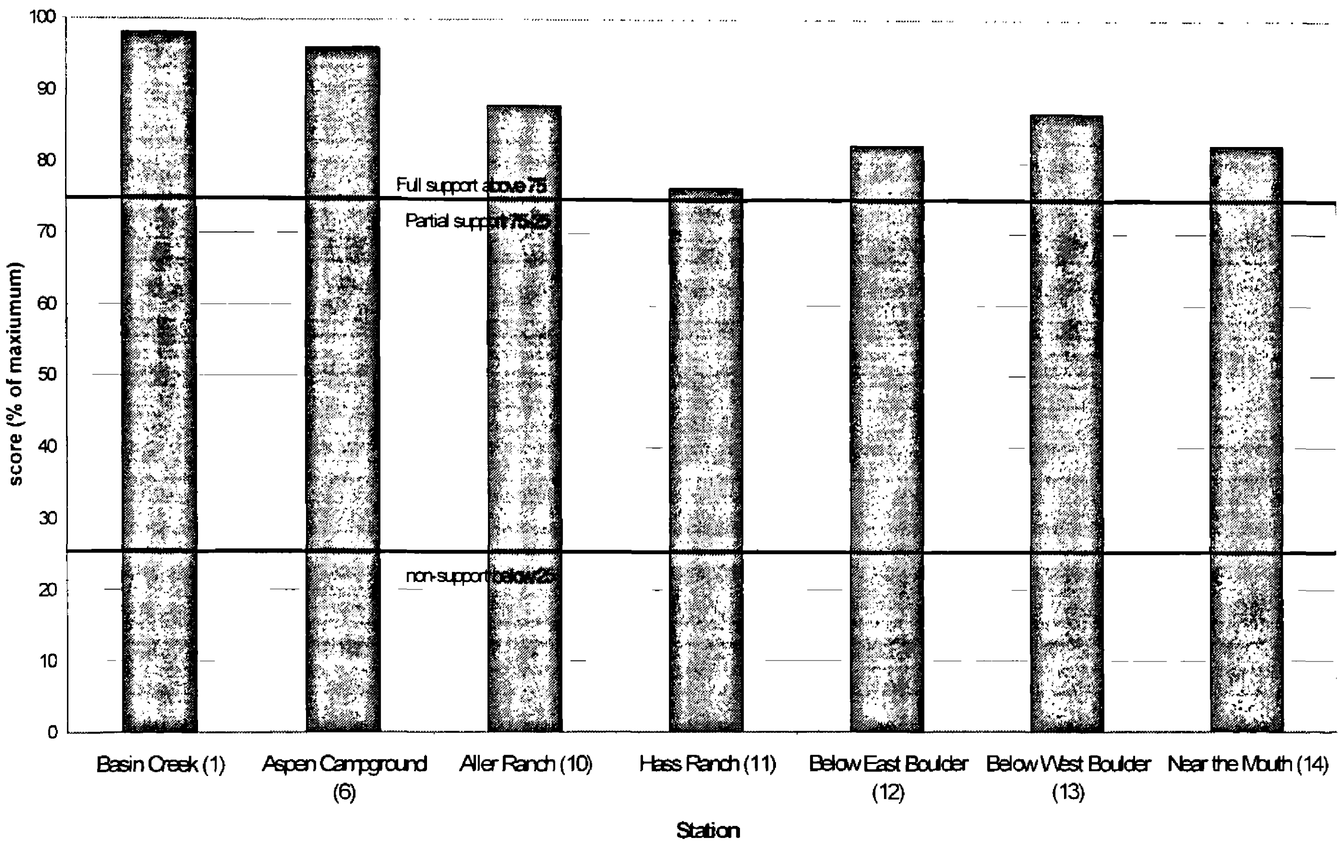


Figure 14. Boulder River Macroinvertebrate Bioassessment Scores, August 1999. (Bollman 2000). *Scores are percent of maximum based on a composite reference for the ecoregion*

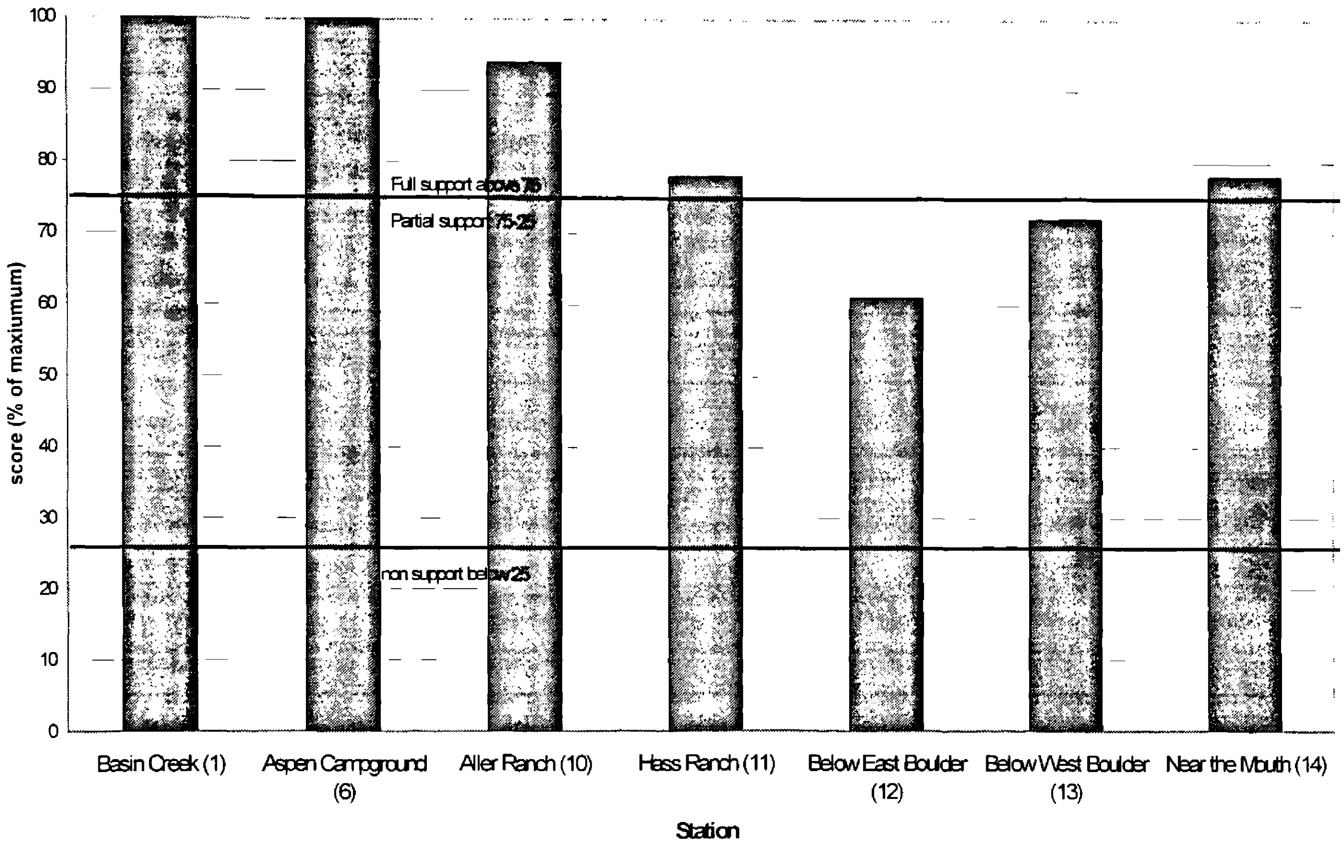


Table 11. Macroinvertebrate Community Assessment, Boulder River. August 1999. (Bollman 2000)

Metric	Basin Creek (1)	Aspen Campground (6)	Aller Ranch (10)	Hass Ranch (11)	Below East Boulder (12)	8 Mile Bridge (13)	Near the Mouth (14)
Ephemeroptera richness	3	3	3	3	3	3	3
Plecoptera richness	3	3	2	2	2	2	3
Trichoptera richness	3	3	3	2	3	3	2
Sensitive taxa richness	3	3	3	2	1	0	1
Percent filterers	3	3	3	2	1	3	3
Percent tolerant taxa	3	3	3	3	1	2	2
Total Score (max = 18)	18	18	17	14	11	12	14
% of maximum	100	100	94	78	61	72	78
*Classification**	*Non-impaired*	*Non-impaired*	*Non-impaired*	*Slight impairment*	*Slight impairment*	*Slight impairment*	*Slight impairment*
*Use support**	*Full support*	*Full support*	*Full support*	*Full support*	*Partial support*	*Partial support*	*Full support*

*Classification: >83% of maximum = Non-impaired; 54-83% Slightly impaired. Use support: >75% of maximum = Full support of beneficial uses; 25-75%=Partial support; <25%=Non-support.

Table 12. Periphyton Community Structure Analysis Results. Boulder River, August 1999. (Bahls 2000)

Periphyton Metric	Basin Creek (1)	Aspen Campground (6)	Aller Ranch (10)	Hass Ranch (11)	Below East Boulder (12)	8 Mile Bridge (13)	Near the Mouth (14)
Shannon Species Diversity	3.5	4.2	4.0	4.2	4.5	<u>2.9</u>	3.3
Pollution Index	2.6	2.6	2.7	2.7	<u>2.4</u>	<u>2.4</u>	<u>2.4</u>
Siltation Index	4.0	15	16	9.7	<u>23</u>	5.6	5.3
Disturbance Index	NC	12	7.3	9.8	6.3	23	18
Number of Species Counted	<u>28</u>	43	45	45	49	44	37
Percent Dominant Species	<u>30</u>	<u>26</u>	<u>25</u>	16	21	<u>44</u>	<u>34</u>
Percent Abnormal Cells	**1.2**	0	0	**1.5**	0	0	<u>0.24</u>
Percent Epithemiaceae	0	0	0	0.36	1.7	0	0

<u>Underlined values</u> indicate full support of aquatic life uses with moderate impairment. **Bold values** indicate partial support of aquatic life uses with moderate impairment. All other values indicate full support of aquatic life uses with no impairment.

Figure 15. Boulder River Stream Reach Physical Assessment Scores, August 1999. *Scores are percent of maximum possible.*

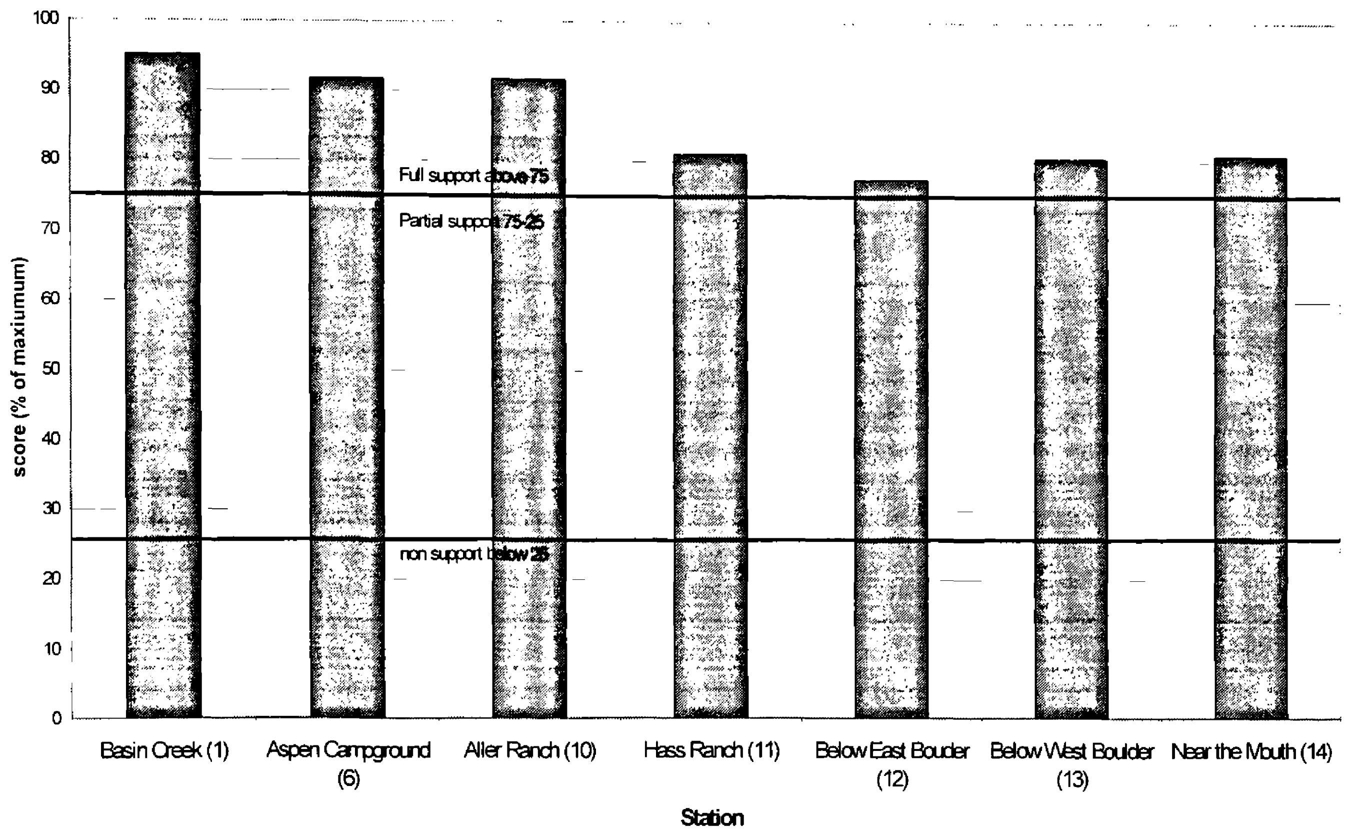


Table 13. Montana Department of Environmental Quality Stream Reach Assessment Score Breakdown for the Boulder River, August 1999.

Max. Possible Score	Parameter	Sampling Station						
		Basin Creek (1)	**Aspen Campground (6)**	**Aller Ranch (10)**	**Hass Ranch (11)**	**Below East Boulder (12)**	**Below West Boulder (13)**	**Near the Mouth (14)**
20	Riparian Width	13	14	13	13	11	12	14
20	Riparian Breaks	20	19	20	13	12	13	14
20	Riparian Characteristics	20	20	18	13	13	12	13
12	Width/Depth Ratio	11	8	8	6	5	7	5
12	Channel Stability and Bar Formation	12	8	9	8	8	12	9
20	Bank Erosion	20	20	20	11	17	19	17
20	Stream Bottom	17	18	20	20	18	20	18
20	Riffles/Pools	20	18	20	20	18	18	18
12	Aquatic Plant Growth	12	12	10	9	5	11	9
12	Turbidity	12	12	12	12	12	12	9
12	Surface oils	12	12	12	12	12	12	12
12	Bottom Materials	12	12	12	12	12	12	12
12	Salinization	12	12	12	12	12	12	12
12	Water odor	12	12	12	12	12	12	12
12	Dewatering	12	12	12	10	10	10	12
12	Fish Cover	11	11	10	11	9	11	8
	Percent of Maximum	95	92	92	81	78	81	81
	Condition*	A	A	A	A	A	A	A

*Condition: A= Non-impairment/Full support (76 -100%); B= Minor impairment/ Partial support (26-75%); C= Impairment/Non support (0-25%).

Table 14. Boulder River Beneficial Use Support by Stream Assessment Parameter

	Basin Creek (1)	**Aspen Campground (6)**	**Aller Ranch (10)**	**Hass Ranch (11)**	**Below East Boulder (12)**	**Below West Boulder (13)**	**Near the Mouth (14)**
Macroinvertebrate Community	Full Support	Full Support	Full Support	Full Support	***Partial Support***	***Partial Support***	Full Support
Periphyton Community	Full Support	Full Support	Full Support	Full Support	Full Support	Full Support	Full Support
Summer Max and Mean Chlorophyll a	Full Support	Full Support	Full Support	Full Support	Full Support	Full Support	Full Support
Nutrients	Full Support	Full Support	Full Support	Full Support	Full Support	Full Support	Full Support
Other Water Chemistry	Full Support	Full Support	Full Support	Full Support	Full Support	Full Support	Full Support
Physical Habitat	Full Support	Full Support	Full Support	Full Support	Full Support	Full Support	Full Support
Metals in Sediment	Full Support	Full Support	Full Support	Full Support	Full Support	Full Support	Full Support

Appendix A

DEQ FIELD FORMS

MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY

STREAM REACH ASSESSMENT FIELD FORM

Instructions: This assessment is meant to be relatively quick, so it is necessarily subjective. As a general rule of thumb a surveyor should be able to complete approximately 20 stream miles per day. This procedure should only be applied to second, third, and fourth order drainages. Each stream will consist of one or more reaches. If more than one reach is assessed, one form will be completed for each reach.

Reaches will be defined by the surveyor and based on relatively homogenous conditions throughout. As a general rule, reach breaks occur where obvious changes in stream condition are detected. The surveyor should be aware of changes such as land use, flow, gradient, vegetation, valley form, and channel substrate. Reach length should generally range between .5 and 20 miles. If the entire reach is not walked the surveyor should select fairly accessible observation points that adequately represent the range of conditions for the reach. Desirable observation points may include the downstream end of the reach, above and below human activities or tributaries.

The surveyor should walk approximately 300' channel distance at each observation point or enough distance to get a representative picture of the situation at that point. If possible, try and observe at least one pool, riffle, and run feature at each site. If a stream crossing structure is present try to observe channel conditions above and below the area influenced by the structure. Dry channels will obviously preclude or restrict the ability to rate parameters such as "turbidity", "water odor", "water surface oils" and "aquatic plant growth"; however, in many cases water is present in isolated pools and the surveyor can rate these parameters. "Riffle/pool spacing" and "Riffle/pool characteristics" ratings may be difficult in dry streams, but evidence in the channel should allow the surveyor to evaluate these parameters.

Again, one legible form should be completed for each reach, with ratings based on a compilation of average conditions for all observation points within the reach. Photos/slides depicting average reach conditions and notable features should be taken if possible. A legible stream map of sufficient scale and detail to identify reaches, observation/photo points, and any unique features should be completed and attached to the assessment forms.

Note: In most cases the information from the assessment forms will be evaluated in the office and entered into a central database by someone other than the field surveyor; therefore, it is extremely important that all recorded information is complete and legible.

RIVER BASIN MAP (for identifying name of river basin recorded on page 2)

STREAM REACH ASSESSMENT FORM

River Basin Name (see map on p.1)__________Stream Name ______________
Recorders Name__________ **Date**___/ /___**County/ies**______________ **Reach Number** (assigned by surveyor, number consecutively starting @ mouth) __________ **Legal Description** [Sec., Town., Range]- **(Downstream end)** _____**(Upstream end)**_____ **Narrative Description Of Reach**__________________________
Quad Sheet Name(s) - optional ____________Photo/Slide # 's if applicable _____ ______________________
____________________**LOOK!—Answer all the following questions. If you are unable to determine record (N/R), or if a parameter is not applicable (N/A).

(Please check the one description that best fits each category)
Predominant vegetation and landscape characteristics in the watershed beyond the immediate riparian zone
______-Perennial vegetation (pasture, rangeland, woodland, etc.), flat to rolling landscape
______-Perennial vegetation, rolling to steep landscape
______-Mixed perennial vegetation and annual crops, flat to rolling landscape
______-Cropland, rolling to steep landscape

Meanders
______-Slight Meandering - Relatively straight channel with only occasional curves. Travel length is basically the same as the straight line distance.
______-Moderate meandering - Easy, gradual bends in the channel path
_____-Extreme meandering - Travel length of flow is greater than twice the straight line distance

Flood Flow Width
______-Floods are confined in narrow canyon with width less that twice that of channel
______-Floods confined to a flow width of 2-3 times the width of the channel
______-Floods are unconfined and spill out onto flat valley bottom

Gradient
______-Steep - Continuous rapids
______-Moderate - Alternating rapids, riffles and smooth surfaced reaches
______-Gradual - Smooth surfaced reaches with occasional riffles
______-Flat - Very rare disruptions in smooth flat surface of stream
______________________________(Please enter a number within the range of the category that best fits)

1.Average width of riparian zone
16-20______ - (> 90 ft wide)
11-15______ -Varies from 15 to 90 ft
6-10 ______ - (3-15 ft)
1-5 ______ -Riparian zone absent

2.Completeness of vegetation in the riparian zone
(Any vegetation functioning to maintain the bank)
16-20______ -Riparian zone intact without breaks in vegetation
11-15______ -Breaks occurring intermittently
6-10 ______ -Breaks frequent with some gullies and scars every 100 - 150 ft.
1-5 ______ -Deeply scarred with active headcutting and gully formation all along reach

Is there evidence of sediment from the upper watershed or riparian area reaching the stream channel?
Yes______No_______If yes, please describe: ________________

3. Characteristics of the Riparian vegetation
16-20______ -Diversity of perennial plant species reflects potential for site; Dense growth (hard to walk through); good plant vigor and age diversity
11 -15_____ -Approximately 60% of climax plant species present; p lant vigor stable, density of growth mostly open (easy to walk through)
6-10 _____ -Little diversity in perennial plant species, and/or age of trees; plants scattered; vigor poor

1-5 _____ -Site is dominated by annual forbs and weeds; few perennial or climax plants present

4. Width/Depth Ratio (Estimated channel width divided by depth as measured at the ordinary high water level). This is the point where high flow normally reaches on the bank and is most easily determined on straight channel sections where the "scoured" channel meets the "permanent" vegetation. Look for characteristics such as terracing, soil changes (rock to soil), presence/absence of vegetation or debris.

10-12 _____ -Width/depth ratio <8
7-9 _____ -Width/depth ratio 8 to 15
4-6 _____ -Width/depth ratio 15 to 25
1-3 _____ -Width/depth ratio > 25 or stream is channelized or channel is an incised gully.

5. Channel stability/bar formation

10-12 _____ -Little or no channel instability resulting from sediment accumulation
7-9 _____ -Some gravel bars of coarse stones and well-washed debris present, little silt
4-6 _____ -Point bars enlarging by gravels, sand and/or silt, new bars forming
1-3 _____ -Channel divided into braids or stream is channelized

6. Bank erosion

16-20 _____ -Little or none evident, banks appear stable and are held firmly by vegetation
11-15 _____ -Erosion occurring on some outside bends and channel constrictions; non-eroding banks stable
6-10 _____ -Erosion common on most outside bends and channel constrictions
1-5 _____ -Erosion predominant on entire channel (straight sections, inside and outside bends, etc.)

(Answer ONE, either 7a. OR 7b.)

7a. Stream bottom - (For Fast moving/Riffle dominated streams)

16-20 _____ -Stony bottom of several sizes packed together, interstices obvious
11-15 _____ -Stony bottom easily moved, with little silt
6-10 _____ -Bottom of silt, gravel and sand, stable in places
1-5 _____ -Uniform bottom of sand and silt loosely held together, stony substrate absent

7b. Stream bottom - (For Slow moving/Pool dominated streams)

16-20 _____ -Mixture of substrate materials with gravel and firm sand prevalent; vascular root mats and submerge vegetation common
11-15 _____ -Mixture of soft sand, mud or clay; mud may be dominant; some vascular root mats and submerge vegetation present
6-10 _____ -All mud or clay, or channelized with sand bottom; little or no submerged vegetation
1-5 _____ -Hardpan clay or bedrock; no vascular root mat or submerged vegetation

(Answer ONE, either 8a. OR 8b.)

8a. Riffle/pool spacing - (For Fast moving/Riffle dominated streams)

16-20 _____ -Distinct, occurring at intervals of 5-7x stream width
11-15 _____ -Irregularly spaced, 8-15x stream width
6-10 _____ -Long pools separating short riffles, meanders absent, 16-25x stream width
1-5 _____ -Meanders and riffles/pools absent or stream channelized, >25x stream width

8b. Riffle/pool characteristics - (For Slow moving/Pool dominated streams)

16-20 _____ -Even mix of deep, shallow, large and small pools
11-15 _____ -Majority of pools large and deep, very few shallow pools
6-10 _____ -Shallow pools more prevalent than deep pools
1-5 _____ -Majority of pools small and shallow or pools absent

9. Aquatic plant growth

10-12 _____ -Not apparent, but rocks or other submerged objects feel slippery
7-9 _____ -In small patches or along channel edges
4-6 _____ -In large patches or discontinuous mats
1-3 _____ -Mats cover bottom (hyper-enriched conditions) or plants not apparent and rocks not slippery (stream

devoid of algae because of toxic conditions)

10.Turbidity

10-12_____ -Clear
7-9 _____ -Slightly off Color
4-6 _____ -Opaquem (can see through)
1-3 _____ -Cloudy (can't see through)
Color:_____________ is rain or runoff influencing turbidity levels today? Yes_____ No_____

STREAM NAME : ________________, REACH NUMBER: _____, DATE __/__/__

11.Water surface oils

10-12_____ -None
7-9 _____ -Slight
4-6 _____ -Moderate
1-3 _____ -Severe
Slick_____ Sheen_____ Flecks_____ Other_____

12.Materials other than sediment on channel bottom (examples: iron or oxides, calcium carbonate) alum

10-12_____ -None
7-9 _____ -Slight
4-6 _____ -Modera te
1-3 _____ -Severe
State color ______________________________

13.Salinization

10-12_____ -None Evident
7-9 _____ -Evidence of salinity is present in the watershed, but no salt cru sts observed in or near the stream
4-6 _____ -Minor evidence of salts in or near the stream. Plant diversity may be reduced or dominated by salt tolerant species.
1-3 _____ -Salt crusts common in or near the stream or on stream banks. Vegetation may be severely reduced due to salt.

14.Water Odor

10-12_____ -None
7-9 _____ -Slight
4-6 _____ -Moderate
1-3 _____ -Strong
Describe Odor - Sewage_____ Petroleum_____ Chemical_____ Natural_____ Other_____

15.Dewatering - From irrigation or natural factors such as subsurface flows. (Assess during critical low flow periods, or you may need to inquire locally about this.)

10-12_____ -No Apparent water loss (irrigation return flow may be supplementin g base flow)
7-9 _____ -Water loss noticeable, however flows are adequate to support aquatic organisms
4-6 _____ -Flow supports aquatic organisms, but habitat, especially riffles, is drastically reduced
1-3 _____ -Channel may be dry or flow low enough to preclude or severely impair aquatic organisms
Are irrigation diversion or return structures present? Yes_____ No_____

16.Amount of fish cover (Relative % of reach with some type of fish cover)

10-12_____ -Extens ive (> 50%)
7-9 _____ -Moderate (25-50%)
4-6 _____ -Sparse (< 25%)
1-3 _____ -Absent or "choking" vegetation only
Fish cover type -mark all that apply with (P)= present, (C)=comm on, (A)= abundant .

Undercut banks_____ Overhanging vegetation _____ Deep Pools _____ Logs/Woody Debris _____ Boulders _____
Rootwads _____ Aquatic Vegetation _____ Other_____
Total_____ - by Total Possible (rated parameters only) _____ X 100 = _____%

(Please check one category below)

IMPAIRMENT/USE SUPPORT VALUES

_____87-100% = NON-IMPAIRED; (FULL SUPPORT)

_____80 - 86% = NON-IMPAIRED; BUT THREATENED; (FULL SUPPORT)

_____71 - 79% = MINOR IMPAIRMENT; (PARTIAL SUPPORT)

_____55 - 70% = MODERATE IMPAIRMENT; (PARTIAL SUPPORT)

_____0 - 54% = SEVERE IMPAIRMENT; (NON-SUPPORT)

TOTAL MAXIMUM COMPARED TO REFERENCE STREAM:

Note: Data should be compared to reference condition.

Total Value: __________

Reference Stream Value: __________

(Enter Value of reference stream in order to compare >75%=Fully supporting results from stream being assessed.) 50-75%=Partially supporting <50%=Non-supporting.

Total Value/Reference Stream Value: __________

MACROINVERTEBRATE HABITAT ASSESSMENT FIELD FORM

RIFFLE / RUN PREVALENCE

Stream ______________________ Site ______________________

Date ______________________ Investigator ______________________

Habitat Parameter	Category			
	Optimal	Sub-Optimal	Marginal	Poor
1A. Riffle Development SCORE (____)	Well-developed riffle; riffle as wide as stream and extends two times width of stream. 9-10	Riffle as wide as stream but length less than two times width. 6-8	Reduced riffle area that is not as wide as stream and its length less than two times width. 3-5	Riffles virtually non-existent 0-2
1B. Benthic Substrate SCORE (____)	Diverse Substrate dominated by cobble. 9-10	Substrate diverse, with abundant cobble but bedrock boulder, fine gravel, or sand prevalent. 6-8	Substrate dominated by bedrock, boulders, fine gravel, sand or silt; cobble present. 3-5	Monotonous fine gravel, sand, silt or bedrock substrate. 0-2
2. Embeddedness SCORE (____)	Gravel, cobble, or boulder particles are between 0-25% surrounded by fine sediment (particles less than 6.35mm [.25"]) 16-20	Gravel, cobble, or boulder particles are between 25-50% surrounded by fine sediment. 11-15	Gravel, cobble, or boulder particles are between 50-75% surrounded by fine sediment. 6-10	Gravel, cobble, or boulder particles are over 75% surrounded by fine sediment. 0-5
3. Channel Alteration (channelization, straightening, dredging, other alterations) SCORE (____)	Channel alterations absent or minimal; stream pattern apparently in natural state. 16-20	Some channelization present, usually in areas of crossings, etc. evidence of past alterations (before past 20 yr) may be present, but more recent channel alteration is not present. 11-15	New embankments present on both banks; and 40 to 80% of the stream reach channelized and disrupted. 6-10	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. 0-5

4. Sediment Deposition SCORE (____)	Little or no enlargement of bars and less than 5% of the bottom affected by sediment deposition. 16-20	Some new increase in bar formation, mostly from coarse gravel; 5-30% of the bottom affected; slight deposition in pools. 11-15	Moderate deposition of new gravel, coarse sand on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition in pools prevalent. 6-10	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition. 0-5

Habitat Parameter	Category			
	Optimal	Sub-Optimal	Marginal	Poor
5. Channel Flow Status SCORE (____)	Water fills baseflow channel; minimal amount of channel substrate exposed. 16-20	Water fills >75% of the baseflow channel; <25% channel substrate exposed. 11-15	Water fills 25-75% of the baseflow channel; riffle substrates mostly exposed. 6-10	Very little water in channel, and mostly present as standing pools. 0-5
6. Bank Stability (Score each bank) Note: determine left or right side while facing downstream. SCORE (____) (left) SCORE (____) (right)	Banks stable; no evidence of erosion or bank failure; little apparent potential for future problems. 9-10	Moderately stable; infrequent, small areas of erosion mostly healed over. 6-8	Moderately unstable; moderate frequency and size of erosional areas; up to 60% of banks in reach have erosion; high erosion potential during high flow. 3-5	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of banks have erosion scars on side-slopes. 0-2
7. Bank Vegetation Protection (note: reduce scores for annual crops and weeds which do not hold soil well, eg knapweed) SCORE (____) (left) SCORE (____) (right)	Over 90% of the streambank surfaces covered by stabilizing vegetation; vegetative disruption minimal or not evident; almost all plants allowed to grow naturally. 9-10	70-90% of the streambank surfaces covered by vegetation; disruption evident, but not affecting full plant growth potential to any great extent; more than one-half of potential plant height evident. 6-8	50-70% of the streambank surfaces covered in vegetation; dsiruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of potential plant height remaining. 3-5	Less than 50% of the streambank surfaces covered by vegetation; extensive disruption of vegetation; vegetation removed to 2 inches or less. 0-2
8. Vegetated Zone Width (score zone for each side of stream) SCORE (____) (left) SCORE (____) (right)	Width of vegetated zone >100 feet. 9-10	Width of vegetated zone 30-100 feet. 6-8	Width of vegetated zone 10-30 feet. 3-5	Width of vegetated zone <10 feet. 0-2

TOTAL SCORE (____)

MOD 5/18/95

21-1-12 FAX

MACROINVERTEBRATE HABITAT ASSESSMENT FIELD FORM GLIDE / POOL PREVALENT STREAMS

Stream ______________________ Date ______________________

Site ______________________ Investigator ______________________

Habitat Parameter	Category			
	Optimal	Sub-Optimal	Marginal	Poor
1. Bottom Substrate / Available Cover SCORE ( )	Greater than 50% mix of snags, submerged logs, undercut banks, rubble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are <u>not</u> new fall and <u>not</u> transient). 16-20	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale). 11-15	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed. 6-10	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking. 0-5
2. Pool Substrate Characterization SCORE ( )	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common. 16-20	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present. 11-15	All mud or clay or sand bottom; little or no root mat; no submerged vegetation. 6-10	Hard-pan clay or bedrock; no root mat or vegetation. 0-5
3. Pool Variability SCORE ( )	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present. 16-20	Majority of pools large-deep; very few shallow. 11-15	Shallow pools much more prevalent than deep pools. 6-10	Majority of pools small-shallow or pools absent. 0-5
4. Channel Alteration (channelization, dredging, staightening, other alterations) SCORE ( )	Channel alteration absent or minimal; stream with normal, sinuous pattern. 16-20	Some channel alteration present, usually in areas of crossings, evidence of past channel alterations, (prior to past 20 yrs) may be present, but more recent channel alteration is not present. 11-15	New embankments present on both banks; channelization may be extensive, usually in urban areas or drainage areas of agriculture lands; and >80% of stream reach channelized and disrupted. 6-10	Extensive channelization; banks shored with gabion or cement; heavily urbanized areas; instream habitat greatly altered or removed entirely. 0-5
5. Sediment Deposition SCORE ( )	Less than 20% of bottom affected; minor accumulation of fine and coarse material at snags and submerged vegetation; little or no enlargement of islands or point bars. 16-20	20-50% affected; moderate accumulation; substantial sediment movement only during major storm event; some new increase in bar formation. 11-15	50-80% affected; major deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial sediment movement during storm events. 6-10	Channelized; mud, silt, and/or sand in braided or nonbraided channels; pools almost absent due to deposition. 0-5

Habitat Parameter	Category			
	Optimal	Sub-Optimal	Marginal	Poor
6. Channel Sinuosity SCORE (____)	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. 16-20	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line. 11-15	The bends in the stream increase the stream length 2 to 1 times longer than if it was in a straight line. 6-10	Channel straight; waterway has been channelized for a long distance. 0-5
7. Channel Flow Status SCORE (____)	Water reaches base of both lower banks and minimal amount of channel substrate is exposed. 16-20	Water fills >75% of the available channel; or <25% of channel substrate is exposed. 11-15	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed. 6-10	Very little water in channel and mostly present as standing pools. 0-5
8. Bank Vegetation Protection (score each blank) Note: determine left or right side by facing downstream. SCORE (____) (LB) SCORE (____) (RB)	More than 90% of the streambank surfaces covered by native vegetation, including trees, understory shrubs, or non-woody macrophytes; Vegetation disruption minimal or not evident; almost all plants allowed to grow naturally. 9-10 9-10	70-90% of the streambank surfaces covered by native vegetation; but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining. 6-8 6-8	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining. 3-5 3-5	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 2 inches or less in average stubble height. 0-2 0-2
9. Bank Stability (score each bank) SCORE (____) (LB) SCORE (____) (RB)	Banks stable; no evidence of erosion or bank failure; little potential for future problems. 9-10 9-10	Moderately stable; infrequent, small areas of erosion mostly healed over. 6-8 6-8	Moderately unstable; up to 60% of banks in reach have areas of erosion; high erosion potential during floods. 3-5 3-5	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars. 0-2 0-2
10. Riparian Vegetation Zone Width (score each bank riparian zone) SCORE (____) (LB) SCORE (____) (RB)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clearcuts, lawns, or crops) have not impacted zone. 9-10 9-10	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally. 3-5 3-5	Width of riparian zone 6-12 meters; human activities have impacted a great deal. 3-5 3-5	Width of riparian zone <8 meters; little or no riparian vegetation due to human activities. 0-2 0-2

TOTAL SCORE (____)

MOD 10/18.94

21-1-12 FRM

Appendix B

WATER QUALITY SAMPLING RESULTS AND METHODS

ENERGY LABORATORIES, INC.
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FAX (406) 252-6069 • 1-800-735-4489 • E-MAIL eli@energylab.com

LABORATORY ANALYSIS REPORT

MT Department of Environmental Quality	Project ID:	JOHN DEARMENT	
Pat Newby	Sample ID:	BOULDER RIVER	Site 1
PO Box 200901	Laboratory ID:	99-55872-1	
Helena, MT 59620	Sample Matrix:	Water	
	Sample Date:		
	Received at lab:	17-Aug-99	Reported: 13-Sep-99

	Results	Units	Qual	Reporting Limit	Regulatory Limit	Method	Analyzed	
Calcium	5	mg/l		1		EPA 200.7	21-Aug-99 0254	RLH
Magnesium	2	mg/l		1		EPA 200.7	21-Aug-99 0254	RLH
Potassium	<1	mg/l		1		EPA 200.7	21-Aug-99 0254	RLH
Sodium	2	mg/l		1		EPA 200.7	21-Aug-99 0254	RLH
Total Hardness as CaCO3	21	mg/l		1		EPA 200.7	21-Aug-99 0254	RLH
Chloride	<1	mg/l		1		EPA 300.0	19-Aug-99 0152	RLH
Sulfate	3	mg/l		1		EPA 300.0	19-Aug-99 0152	RLH
Alkalinity as CaCO3	35	mg/l		1		EPA 310.1	18-Aug-99 1111	LDV
Total Dissolved Solids at 180 C	43	mg/l		10		EPA 160.1	18-Aug-99 1315	LDV
Nitrate + Nitrite as N	<0.01	mg/l		0.01		EPA 353.2	17-Aug-99 1652	BAS
Total Kjeldahl Nitrogen	<0.1	mg/l		0.1		SM 4500N	25-Aug-99 0730	BS
Total Phosphorus	0.012	mg/l		0.001		EPA 365.1	25-Aug-99 1534	BAS
Cation-Anion Balance	-20.69	%						
Sodium Adsorption Ratio	0.19							
Total Suspended Solids	< 10(2)	mg/l	J	10		EPA 160.2	18-Aug-99 1630	ND
Aluminum, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	19-Aug-99 1508	TDB
Antimony, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	24-Aug-99 2043	LAB
Arsenic, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	24-Aug-99 2043	LAB
Barium, Total Recoverable	0.024	mg/l		0.005		EPA 200.7	19-Aug-99 1508	TDB
Beryllium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.7	19-Aug-99 1508	TDB
Boron, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	19-Aug-99 1508	TDB
Cadmium, Total Recoverable	<0.0001	mg/l		0.0001		EPA 200.8	24-Aug-99 2043	LAB
Chromium, Total Recoverable	0.003	mg/l		0.001		EPA 200.8	24-Aug-99 2043	LAB
Cobalt, Total Recoverable	<0.01	mg/l		0.01		EPA 200.7	19-Aug-99 1508	TDB
Copper, Total Recoverable	0.001	mg/l		0.001		EPA 200.8	24-Aug-99 2043	LAB
Iron, Total Recoverable	0.07	mg/l		0.01		EPA 200.7	19-Aug-99 1508	TDB
Lead, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	24-Aug-99 2043	LAB
Manganese, Total Recoverable	<0.005	mg/l		0.005		EPA 200.7	19-Aug-99 1508	TDB
Mercury, Total Recoverable	<0.0001	mg/l		0.0001		EPA 245.2	24-Aug-99 1315	FMB
Molybdenum, Total Recoverable	<0.005	mg/l		0.005		EPA 200.8	24-Aug-99 2043	LAB
Nickel, Total Recoverable	<0.01	mg/l		0.01		EPA 200.8	24-Aug-99 2043	LAB
Selenium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	24-Aug-99 2043	LAB
Silicon, Total Recoverable	3.0	mg/l		0.1		EPA 200.7	19-Aug-99 1508	TDB
Silver, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	24-Aug-99 2043	LAB
Strontium, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	19-Aug-99 1508	TDB
Thallium, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	24-Aug-99 2043	LAB
Zinc, Total Recoverable	0.02	mg/l		0.01		EPA 200.7	19-Aug-99 1508	TDB

99-55872.XLS

ENERGY LABORATORIES, INC.
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LABORATORY ANALYSIS REPORT

MT Department of Environmental Quality
Pat Newby
PO Box 200901
Helena, MT 59620

Project ID: JOHN DEARMENT
Sample ID: BOULDER RIVER Site 6
Laboratory ID: 99-55872-2
Sample Matrix: Water
Sample Date: 09-Aug-99
Received at lab: 17-Aug-99
Reported: 13-Sep-99

	Results	Units	Qual	Reporting Limit	Regulatory Limit	Method	Analyzed	
Calcium	7	mg/l		1		EPA 200.7	21-Aug-99 0257	RLH
Magnesium	2	mg/l		1		EPA 200.7	21-Aug-99 0257	RLH
Potassium	<1	mg/l		1		EPA 200.7	21-Aug-99 0257	RLH
Sodium	2	mg/l		1		EPA 200.7	21-Aug-99 0257	RLH
Total Hardness as CaCO3	26	mg/l		1		EPA 200.7	21-Aug-99 0257	RLH
Chloride	<1	mg/l		1		EPA 300.0	19-Aug-99 0201	RLH
Sulfate	3	mg/l		1		EPA 300.0	19-Aug-99 0201	RLH
Alkalinity as CaCO3	30	mg/l		1		EPA 310.1	18-Aug-99 1116	LDV
Total Dissolved Solids at 180 C	44	mg/l		10		EPA 160.1	18-Aug-99 1315	LDV
Nitrate + Nitrite as N	0.01	mg/l		0.01		EPA 353.2	17-Aug-99 1652	BAS
Total Kjeldahl Nitrogen	<0.1	mg/l		0.1		SM 4500N	25-Aug-99 0730	BS
Total Phosphorus	0.010	mg/l		0.001		EPA 365.1	25-Aug-99 1535	BAS
Cation-Anion Balance	-4.88	%						
Sodium Adsorption Ratio	0.17							
Total Suspended Solids	<10(1)	mg/l	J	10		EPA 160.2	18-Aug-99 1630	ND
Aluminum, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	20-Aug-99 1750	RLH
Antimony, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	19-Aug-99 1556	LAB
Arsenic, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	19-Aug-99 1556	LAB
Barium, Total Recoverable	0.022	mg/l		0.005		EPA 200.7	20-Aug-99 1750	RLH
Beryllium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.7	20-Aug-99 1750	RLH
Boron, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	20-Aug-99 1750	RLH
Cadmium, Total Recoverable	<0.0001	mg/l		0.0001		EPA 200.8	19-Aug-99 1556	LAB
Chromium, Total Recoverable	0.002	mg/l		0.001		EPA 200.8	19-Aug-99 1556	LAB
Cobalt, Total Recoverable	<0.01	mg/l		0.01		EPA 200.7	20-Aug-99 1750	RLH
Copper, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	19-Aug-99 1556	LAB
Iron, Total Recoverable	0.04	mg/l		0.01		EPA 200.7	20-Aug-99 1750	RLH
Lead, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	19-Aug-99 1556	LAB
Manganese, Total Recoverable	<0.005	mg/l		0.005		EPA 200.7	20-Aug-99 1750	RLH
Mercury, Total Recoverable	<0.0001	mg/l		0.0001		EPA 200.8	19-Aug-99 1556	LAB
Molybdenum, Total Recoverable	<0.005	mg/l		0.005		EPA 200.8	19-Aug-99 1556	LAB
Nickel, Total Recoverable	<0.01	mg/l		0.01		EPA 200.8	19-Aug-99 1556	LAB
Selenium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	19-Aug-99 1556	LAB
Silicon, Total Recoverable	4.6	mg/l		0.1		EPA 200.7	20-Aug-99 1750	RLH
Silver, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	19-Aug-99 1556	LAB
Strontium, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	20-Aug-99 1750	RLH
Thallium, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	19-Aug-99 1556	LAB
Zinc, Total Recoverable	<0.01	mg/l		0.01		EPA 200.7	20-Aug-99 1750	RLH

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LABORATORY ANALYSIS REPORT

MT Department of Environmental Quality	Project ID:	JOHN DEARMENT	
Pat Newby	Sample ID:	BOULDER RIVER	Site 10
PO Box 200901	Laboratory ID:	99-55872-3	
Helena, MT 59620	Sample Matrix:	Water	
	Sample Date:	14-Aug-99	
	Received at lab:	17-Aug-99	Reported: 13-Sep-99

	Results	Units	Qual	Reporting Limit	Regulatory Limit	Method	Analyzed	
Calcium	8	mg/l		1		EPA 200.7	21-Aug-99 0301	RLH
Magnesium	3	mg/l		1		EPA 200.7	21-Aug-99 0301	RLH
Potassium	1	mg/l		1		EPA 200.7	21-Aug-99 0301	RLH
Sodium	2	mg/l		1		EPA 200.7	21-Aug-99 0301	RLH
Total Hardness as CaCO3	32	mg/l		1		EPA 200.7	21-Aug-99 0301	RLH
Chloride	<1	mg/l		1		EPA 300.0	19-Aug-99 0210	RLH
Sulfate	5	mg/l		1		EPA 300.0	19-Aug-99 0210	RLH
Alkalinity as CaCO3	33	mg/l		1		EPA 310.1	18-Aug-99 1121	LDV
Total Dissolved Solids at 180 C	48	mg/l		10		EPA 160.1	18-Aug-99 1315	LDV
Nitrate + Nitrite as N	0.02	mg/l		0.01		EPA 353.2	17-Aug-99 1653	BAS
Total Kjeldahl Nitrogen	<0.1	mg/l		0.1		SM 4500N	25-Aug-99 0730	BS
Total Phosphorus	0.010	mg/l		0.001		EPA 365.1	25-Aug-99 1537	BAS
Cation-Anion Balance	-0.36	%						
Sodium Adsorption Ratio	0.15							
Total Suspended Solids	<10(1)	mg/l	J	10		EPA 160.2	18-Aug-99 1630	ND
Aluminum, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	20-Aug-99 1752	RLH
Antimony, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	19-Aug-99 1653	LAB
Arsenic, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	19-Aug-99 1653	LAB
Barium, Total Recoverable	0.022	mg/l		0.005		EPA 200.7	20-Aug-99 1752	RLH
Beryllium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.7	20-Aug-99 1752	RLH
Boron, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	20-Aug-99 1752	RLH
Cadmium, Total Recoverable	<0.0001	mg/l		0.0001		EPA 200.8	19-Aug-99 1653	LAB
Chromium, Total Recoverable	0.001	mg/l		0.001		EPA 200.8	19-Aug-99 1653	LAB
Cobalt, Total Recoverable	<0.01	mg/l		0.01		EPA 200.7	20-Aug-99 1752	RLH
Copper, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	19-Aug-99 1653	LAB
Iron, Total Recoverable	0.08	mg/l		0.01		EPA 200.7	20-Aug-99 1752	RLH
Lead, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	19-Aug-99 1653	LAB
Manganese, Total Recoverable	<0.005	mg/l		0.005		EPA 200.7	20-Aug-99 1752	RLH
Mercury, Total Recoverable	<0.0001	mg/l		0.0001		EPA 200.8	19-Aug-99 1653	LAB
Molybdenum, Total Recoverable	<0.005	mg/l		0.005		EPA 200.8	19-Aug-99 1653	LAB
Nickel, Total Recoverable	<0.01	mg/l		0.01		EPA 200.8	19-Aug-99 1653	LAB
Selenium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	19-Aug-99 1653	LAB
Silicon, Total Recoverable	4.7	mg/l		0.1		EPA 200.7	20-Aug-99 1752	RLH
Silver, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	19-Aug-99 1653	LAB
Strontium, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	20-Aug-99 1752	RLH
Thallium, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	19-Aug-99 1653	LAB
Zinc, Total Recoverable	<0.01	mg/l		0.01		EPA 200.7	20-Aug-99 1752	RLH

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LABORATORY ANALYSIS REPORT

MT Department of Environmental Quality	Project ID:	JOHN DEARMENT	
Pat Newby	Sample ID:	BOULDER RIVER	Site 11
PO Box 200901	Laboratory ID:	99-55872-4	
Helena, MT 59620	Sample Matrix:	Water	
	Sample Date:	14-Aug-99	
	Received at lab:	17-Aug-99	Reported: 13-Sep-99

	Results	Units	Qual	Reporting Limit	Regulatory Limit	Method	Analyzed	
Calcium	10	mg/l		1		EPA 200.7	21-Aug-99 0303	RLH
Magnesium	3	mg/l		1		EPA 200.7	21-Aug-99 0303	RLH
Potassium	1	mg/l		1		EPA 200.7	21-Aug-99 0303	RLH
Sodium	2	mg/l		1		EPA 200.7	21-Aug-99 0303	RLH
Total Hardness as CaCO3	37	mg/l		1		EPA 200.7	21-Aug-99 0303	RLH
Chloride	<1	mg/l		1		EPA 300.0	19-Aug-99 0218	RLH
Sulfate	6	mg/l		1		EPA 300.0	19-Aug-99 0218	RLH
Alkalinity as CaCO3	38	mg/l		1		EPA 310.1	18-Aug-99 1125	LDV
Total Dissolved Solids at 180 C	55	mg/l		10		EPA 160.1	18-Aug-99 1315	LDV
Nitrate + Nitrite as N	<0.01	mg/l		0.01		EPA 353.2	17-Aug-99 1655	BAS
Total Kjeldahl Nitrogen	<0.1	mg/l		0.1		SM 4500N	25-Aug-99 0730	BS
Total Phosphorus	0.005	mg/l		0.001		EPA 365.1	25-Aug-991538	BAS
Cation-Anion Balance	-1.52	%						
Sodium Adsorption Ratio	0.14							
Total Suspended Solids	<10(2)	mg/l	J	10		EPA 160.2	18-Aug-99 1630	ND
Aluminum, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	20-Aug-99 1756	RLH
Antimony, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	19-Aug-99 1658	LAB
Arsenic, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	19-Aug-99 1658	LAB
Barium, Total Recoverable	0.023	mg/l		0.005		EPA 200.7	20-Aug-99 1756	RLH
Beryllium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.7	20-Aug-99 1756	RLH
Boron, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	20-Aug-99 1756	RLH
Cadmium, Total Recoverable	<0.0001	mg/l		0.0001		EPA 200.8	19-Aug-99 1658	LAB
Chromium, Total Recoverable	0.002	mg/l		0.001		EPA 200.8	19-Aug-99 1658	LAB
Cobalt, Total Recoverable	<0.01	mg/l		0.01		EPA 200.7	20-Aug-99 1756	RLH
Copper, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	19-Aug-99 1658	LAB
Iron, Total Recoverable	0.06	mg/l		0.01		EPA 200.7	20-Aug-99 1756	RLH
Lead, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	19-Aug-99 1658	LAB
Manganese, Total Recoverable	<0.005	mg/l		0.005		EPA 200.7	20-Aug-99 1756	RLH
Mercury, Total Recoverable	<0.0001	mg/l		0.0001		EPA 200.8	19-Aug-99 1658	LAB
Molybdenum, Total Recoverable	<0.005	mg/l		0.005		EPA 200.8	19-Aug-99 1658	LAB
Nickel, Total Recoverable	<0.01	mg/l		0.01		EPA 200.8	19-Aug-99 1658	LAB
Selenium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	19-Aug-99 1658	LAB
Silicon, Total Recoverable	4.5	mg/l		0.1		EPA 200.7	20-Aug-99 1756	RLH
Silver, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	19-Aug-99 1658	LAB
Strontium, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	20-Aug-99 1756	RLH
Thallium, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	19-Aug-99 1658	LAB
Zinc, Total Recoverable	0.02	mg/l		0.01		EPA 200.7	20-Aug-99 1756	RLH

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LABORATORY ANALYSIS REPORT

MT Department of Environmental Quality	Project ID:	JOHN DEARMENT
Pat Newby	Sample ID:	BOULDER RIVER Site 12
PO Box 200901	Laboratory ID:	99-55872-5
Helena, MT 59620	Sample Matrix:	Water
	Sample Date:	13-Aug-99
	Received at lab:	17-Aug-99
	Reported:	13-Sep-99

	Results	Units	Qual	Reporting Limit	Regulatory Limit	Method	Analyzed	
Calcium	13	mg/l		1		EPA 200.7	21-Aug-99 0305	RLH
Magnesium	4	mg/l		1		EPA 200.7	21-Aug-99 0305	RLH
Potassium	1	mg/l		1		EPA 200.7	21-Aug-99 0305	RLH
Sodium	2	mg/l		1		EPA 200.7	21-Aug-99 0305	RLH
Total Hardness as CaCO3	49	mg/l		1		EPA 200.7	21-Aug-99 0305	RLH
Chloride	<1	mg/l		1		EPA 300.0	19-Aug-99 0227	RLH
Sulfate	15	mg/l		1		EPA 300.0	19-Aug-99 0227	RLH
Alkalinity as CaCO3	45	mg/l		1		EPA 310.1	18-Aug-99 1130	LDV
Total Dissolved Solids at 180 C	75	mg/l		10		EPA 160.1	18-Aug-99 1315	LDV
Nitrate + Nitrite as N	0.01	mg/l		0.01		EPA 353.2	17-Aug-99 1656	BAS
Total Kjeldahl Nitrogen	<0.1	mg/l		0.1		SM 4500N	25-Aug-99 0730	BS
Total Phosphorus	0.012	mg/l		0.001		EPA 365.1	25-Aug-99 1539	BAS
Cation-Anion Balance	-5.29	%						
Sodium Adsorption Ratio	0.12							
Total Suspended Solids	<10(1)	mg/l	J	10		EPA 160.2	18-Aug-99 1630	ND
Aluminum, Total Recoverable	0.2	mg/l		0.1		EPA 200.7	19-Aug-99 1641	TDB
Antimony, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	24-Aug-99 2053	LAB
Arsenic, Total Recoverable	0.001	mg/l		0.001		EPA 200.8	24-Aug-99 2053	LAB
Barium, Total Recoverable	0.034	mg/l		0.005		EPA 200.7	19-Aug-99 1641	TDB
Beryllium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.7	19-Aug-99 1641	TDB
Boron, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	19-Aug-99 1641	TDB
Cadmium, Total Recoverable	<0.0001	mg/l		0.0001		EPA 200.8	24-Aug-99 2053	LAB
Chromium, Total Recoverable	0.003	mg/l		0.001		EPA 200.8	24-Aug-99 2053	LAB
Cobalt, Total Recoverable	<0.01	mg/l		0.01		EPA 200.7	19-Aug-99 1641	TDB
Copper, Total Recoverable	0.001	mg/l		0.001		EPA 200.8	24-Aug-99 2053	LAB
Iron, Total Recoverable	0.28	mg/l		0.01		EPA 200.7	19-Aug-99 1641	TDB
Lead, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	24-Aug-99 2053	LAB
Manganese, Total Recoverable	<0.005	mg/l		0.005		EPA 200.7	19-Aug-99 1641	TDB
Mercury, Total Recoverable	<0.0001	mg/l		0.0001		EPA 245.2	24-Aug-99 1315	FMB
Molybdenum, Total Recoverable	<0.005	mg/l		0.005		EPA 200.8	24-Aug-99 2053	LAB
Nickel, Total Recoverable	<0.01	mg/l		0.01		EPA 200.8	24-Aug-99 2053	LAB
Selenium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	24-Aug-99 2053	LAB
Silicon, Total Recoverable	5.9	mg/l		0.1		EPA 200.7	19-Aug-99 1641	TDB
Silver, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	24-Aug-99 2053	LAB
Strontium, Total Recoverable	0.1	mg/l		0.1		EPA 200.7	19-Aug-99 1641	TDB
Thallium, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	24-Aug-99 2053	LAB
Zinc, Total Recoverable	<0.01	mg/l		0.01		EPA 200.7	19-Aug-99 1641	TDB

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LABORATORY ANALYSIS REPORT

MT Department of Environmental Quality
Pat Newby
PO Box 200901
Helena, MT 59620

Project ID:	JOHN DEARMENT
Sample ID:	BOULDER RIVER Site 13
Laboratory ID:	99-55872-6
Sample Matrix:	Water
Sample Date:	13-Aug-99
Received at lab:	17-Aug-99
Reported:	13-Sep-99

	Results	Units	Qual	Reporting Limit	Regulatory Limit	Method	Analyzed	
Calcium	19	mg/l		1		EPA 200.7	21-Aug-99 0311	RLH
Magnesium	5	mg/l		1		EPA 200.7	21-Aug-99 0311	RLH
Potassium	1	mg/l		1		EPA 200.7	21-Aug-99 0311	RLH
Sodium	3	mg/l		1		EPA 200.7	21-Aug-99 0311	RLH
Total Hardness as CaCO3	68	mg/l		1		EPA 200.7	21-Aug-99 0311	RLH
Chloride	<1	mg/l		1		EPA 300.0	19-Aug-99 0236	RLH
Sulfate	14	mg/l		1		EPA 300.0	19-Aug-99 0236	RLH
Alkalinity as CaCO3	64	mg/l		1		EPA 310.1	18-Aug-99 1135	LDV
Total Dissolved Solids at 180 C	90	mg/l		10		EPA 160.1	18-Aug-99 1315	LDV
Nitrate + Nitrite as N	0.03	mg/l		0.01		EPA 353.2	17-Aug-99 1657	BAS
Total Kjeldahl Nitrogen	<0.1	mg/l		0.1		SM 4500N	25-Aug-99 0730	BS
Total Phosphorus	0.011	mg/l		0.001		EPA 365.1	25-Aug-99 1540	BAS
Cation-Anion Balance	-1.81	%						
Sodium Adsorption Ratio	0.16							
Total Suspended Solids	< 10(2)	mg/l	J	10		EPA 160.2	18-Aug-99 1630	ND
Aluminum, Total Recoverable	0.2	mg/l		0.1		EPA 200.7	19-Aug-99 1645	TDB
Antimony, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	24-Aug-99 2058	LAB
Arsenic, Total Recoverable	0.001	mg/l		0.001		EPA 200.8	24-Aug-99 2058	LAB
Barium, Total Recoverable	0.040	mg/l		0.005		EPA 200.7	19-Aug-99 1645	TDB
Beryllium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.7	19-Aug-99 1645	TDB
Boron, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	19-Aug-99 1645	TDB
Cadmium, Total Recoverable	<0.0001	mg/l		0.0001		EPA 200.8	24-Aug-99 2058	LAB
Chromium, Total Recoverable	0.003	mg/l		0.001		EPA 200.8	24-Aug-99 2058	LAB
Cobalt, Total Recoverable	<0.01	mg/l		0.01		EPA 200.7	19-Aug-99 1645	TDB
Copper, Total Recoverable	0.001	mg/l		0.001		EPA 200.8	24-Aug-99 2058	LAB
Iron, Total Recoverable	0.16	mg/l		0.01		EPA 200.7	19-Aug-99 1645	TDB
Lead, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	24-Aug-99 2058	LAB
Manganese, Total Recoverable	0.013	mg/l		0.005		EPA 200.7	19-Aug-99 1645	TDB
Mercury, Total Recoverable	<0.0001	mg/l		0.0001		EPA 245.2	24-Aug-99 1315	FMB
Molybdenum, Total Recoverable	<0.005	mg/l		0.005		EPA 200.8	24-Aug-99 2058	LAB
Nickel, Total Recoverable	<0.01	mg/l		0.01		EPA 200.8	24-Aug-99 2058	LAB
Selenium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	24-Aug-99 2058	LAB
Silicon, Total Recoverable	5.1	mg/l		0.1		EPA 200.7	19-Aug-99 1645	TDB
Silver, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	24-Aug-99 2058	LAB
Strontium, Total Recoverable	0.1	mg/l		0.1		EPA 200.7	19-Aug-99 1645	TDB
Thallium, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	24-Aug-99 2058	LAB
Zinc, Total Recoverable	<0.01	mg/l		0.01		EPA 200.7	19-Aug-99 1645	TDB

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LABORATORY ANALYSIS REPORT

MT Department of Environmental Quality
Pat Newby
PO Box 200901
Helena, MT 59620

Project ID: JOHN DEARMENT
Sample ID: BOULDER RIVER . Site 14
Laboratory ID: 99-55872-7
Sample Matrix: Water
Sample Date: 13-Aug-99
Received at lab: 17-Aug-99
Reported: 13-Sep-99

	Results	Units	Qual	Reporting Limit	Regulatory Limit	Method	Analyzed	
Calcium	22	mg/l		1		EPA 200.7	21-Aug-99 0313	RLH
Magnesium	6	mg/l		1		EPA 200.7	21-Aug-99 0313	RLH
Potassium	1	mg/l		1		EPA 200.7	21-Aug-99 0313	RLH
Sodium	3	mg/l		1		EPA 200.7	21-Aug-99 0313	RLH
Total Hardness as CaCO3	80	mg/l		1		EPA 200.7	21-Aug-99 0313	RLH
Chloride	<1	mg/l		1		EPA 300.0	19-Aug-99 0245	RLH
Sulfate	14	mg/l		1		EPA 300.0	19-Aug-99 0245	RLH
Alkalinity as CaCO3	75	mg/l		1		EPA 310.1	18-Aug-99 1139	LDV
Total Dissolved Solids at 180 C	100	mg/l		10		EPA 160.1	18-Aug-99 1315	LDV
Nitrate + Nitrite as N	0.02	mg/l		0.01		EPA 353.2	17-Aug-99 1657	BAS
Total Kjeldahl Nitrogen	<0.1	mg/l		0.1		SM 4500N	26-Aug-99 0700	BS
Total Phosphorus	0.010	mg/l		0.001		EPA 365.1	25-Aug-99 1541	BAS
Cation-Anion Balance	-1.24	%						
Sodium Adsorption Ratio	0.15							
Total Suspended Solids	<10(2)	mg/l	J	10		EPA 160.2	18-Aug-99 1630	ND
Aluminum, Total Recoverable	0.1	mg/l		0.1		EPA 200.7	19-Aug-99 1646	TDB
Antimony, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	24-Aug-99 2129	LAB
Arsenic, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	24-Aug-99 2129	LAB
Barium, Total Recoverable	0.045	mg/l		0.005		EPA 200.7	19-Aug-99 1646	TDB
Beryllium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.7	19-Aug-99 1646	TDB
Boron, Total Recoverable	<0.1	mg/l		0.1		EPA 200.7	19-Aug-99 1646	TDB
Cadmium, Total Recoverable	<0.0001	mg/l		0.0001		EPA 200.8	24-Aug-99 2129	LAB
Chromium, Total Recoverable	0.002	mg/l		0.001		EPA 200.8	24-Aug-99 2129	LAB
Cobalt, Total Recoverable	<0.01	mg/l		0.01		EPA 200.7	19-Aug-99 1646	TDB
Copper, Total Recoverable	0.001	mg/l		0.001		EPA 200.8	24-Aug-99 2129	LAB
Iron, Total Recoverable	0.11	mg/l		0.01		EPA 200.7	19-Aug-99 1646	TDB
Lead, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	24-Aug-99 2129	LAB
Manganese, Total Recoverable	<0.005	mg/l		0.005		EPA 200.7	19-Aug-99 1646	TDB
Mercury, Total Recoverable	<0.0001	mg/l		0.0001		EPA 245.2	24-Aug-99 1315	FMB
Molybdenum, Total Recoverable	<0.005	mg/l		0.005		EPA 200.8	24-Aug-99 2129	LAB
Nickel, Total Recoverable	<0.01	mg/l		0.01		EPA 200.8	24-Aug-99 2129	LAB
Selenium, Total Recoverable	<0.001	mg/l		0.001		EPA 200.8	24-Aug-99 2129	LAB
Silicon, Total Recoverable	5.0	mg/l		0.1		EPA 200.7	19-Aug-99 1646	TDB
Silver, Total Recoverable	<0.003	mg/l		0.003		EPA 200.8	24-Aug-99 2129	LAB
Strontium, Total Recoverable	0.2	mg/l		0.1		EPA 200.7	19-Aug-99 1646	TDB
Thallium, Total Recoverable	<0.002	mg/l		0.002		EPA 200.8	24-Aug-99 2129	LAB
Zinc, Total Recoverable	<0.01	mg/l		0.01		EPA 200.7	19-Aug-99 1646	TDB

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Appendix C

METALS IN FINE BED SEDIMENT SAMPLING RESULTS AND METHODS

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LABORATORY REPORT

TO:	Pat Newby	LAB NO.:	001-00-50329
ADDRESS:	MT DEQ	DATE:	02/08/00 mf
	2009 Phoenix Ave.		
	Helena, MT 59620		

WASTE ANALYSIS

Boulder River
Submitted 01/13/00 Site 1

Constituents	Detection Limit, µg/g (ppm)	Dry Weight Basis, µg/g (ppm)	EPA Method	Date & Time Analyzed	Analyst's Initials
Organic Carbon	0.02 % by wt	0.27 % by wt	(1)	01/26/00 @ 1000	SM
Total Metals(2)					
Aluminum	5	4700	6010	01/21/00 @ 2052	RLH
Antimony	5	<5	6020	01/28/00 @ 1854	LAB
Arsenic	5	<5	6020	01/28/00 @ 1854	LAB
Barium	5	100	6010	01/21/00 @ 2052	RLH
Beryllium	5	<5	6010	01/21/00 @ 2052	RLH
Cadmium	5	<5	6010	01/21/00 @ 2052	RLH
Calcium	50	2900	6010	01/21/00 @ 2052	RLH
Chromium	5	20	6010	01/21/00 @ 2052	RLH
Copper	5	65	6010	01/21/00 @ 2052	RLH
Iron	5	9900	6010	01/21/00 @ 2052	RLH
Lead	5	9	6010	01/21/00 @ 2052	RLH
Magnesium	50	6100	6010	01/21/00 @ 2052	RLH
Manganese	5	200	6010	01/21/00 @ 2052	RLH
Nickel	5	26	6010	01/21/00 @ 2052	RLH
Potassium	50	690	6010	01/21/00 @ 2052	RLH
Selenium	5	<5	6020	01/28/00 @ 1854	LAB
Silver	5	<5	6010	01/21/00 @ 2052	RLH
Sodium	50	280	6010	01/21/00 @ 2052	RLH
Thallium	5	<5	6020	01/28/00 @ 1854	LAB
Zinc	5	26	6010	01/21/00 @ 2052	RLH

(1) ASA Monograph No. 9, Method 29-3.5.2.
(2) Sample digested 01/19/00 by HNO_3 Digestion.

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LABORATORY REPORT

TO: Pat Newby
ADDRESS: MT DEQ
2209 Phoenix Ave.
Helena, MT 59620

LAB NO.: 002-00-50329
DATE: 02/08/00 mf

WASTE ANALYSIS

Boulder River Site 6
Sampled 08/12/99
Submitted 01/13/00

Constituents	Detection Limit, µg/g (ppm)	Dry Weight Basis, µg/g (ppm)	EPA Method	Date & Time Analyzed	Analyst's Initials
Organic Carbon	0.02 % by wt	0.28 % by wt	[1]	01/26/00 @ 1000	SM
Total Metals[2]					
Aluminum	5	4800	6010	01/21/00 @ 2054	RLH
Antimony	5	<5	6020	01/28/00 @ 1859	LAB
Arsenic	5	<5	6020	01/28/00 @ 1859	LAB
Barium	5	69	6010	01/21/00 @ 2054	RLH
Beryllium	5	<5	6010	01/21/00 @ 2054	RLH
Cadmium	5	<5	6010	01/21/00 @ 2054	RLH
Calcium	50	2100	6010	01/21/00 @ 2054	RLH
Chromium	5	28	6010	01/21/00 @ 2054	RLH
Copper	5	7	6010	01/21/00 @ 2054	RLH
Iron	5	11000	6010	01/21/00 @ 2054	RLH
Lead	5	<5	6010	01/21/00 @ 2054	RLH
Magnesium	50	3700	6010	01/21/00 @ 2054	RLH
Manganese	5	170	6010	01/21/00 @ 2054	RLH
Nickel	5	17	6010	01/21/00 @ 2054	RLH
Potassium	50	800	6010	01/21/00 @ 2054	RLH
Selenium	5	<5	6020	01/28/00 @ 1859	LAB
Silver	5	<5	6010	01/21/00 @ 2054	RLH
Sodium	50	170	6010	01/21/00 @ 2054	RLH
Thallium	5	<5	6020	01/28/00 @ 1859	LAB
Zinc	5	16	6010	01/21/00 @ 2054	RLH

[1] ASA Monograph No. 9, Method 29-3.5.2.
[2] Sample digested 01/19/00 by HNO_3 Digestion.

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LABORATORY REPORT

TO: Pat Newby
ADDRESS: MT DEQ
2209 Phoenix Ave.
Helena, MT 59620

LAB NO.: 003-00-50329
DATE: 02/08/00 mf

WASTE ANALYSIS

Boulder River Site 10
Sampled 08/14/99
Submitted 01/13/00

Constituents	Detection Limit, µg/g (ppm)	Dry Weight Basis, µg/g (ppm)	EPA Method	Date & Time Analyzed	Analyst's Initials
Organic Carbon	0.02 % by wt	0.25 % by wt	[1]	01/26/00 @ 1000	SM
Total Metals[2]					
Aluminum	5	6700	6010	01/21/00 @ 2100	RLH
Antimony	5	<5	6020	01/28/00 @ 1904	LAB
Arsenic	5	<5	6020	01/28/00 @ 1904	LAB
Barium	5	86	6010	01/21/00 @ 2100	RLH
Beryllium	5	<5	6010	01/21/00 @ 2100	RLH
Cadmium	5	<5	6010	01/21/00 @ 2100	RLH
Calcium	50	2400	6010	01/21/00 @ 2100	RLH
Chromium	5	40	6010	01/21/00 @ 2100	RLH
Copper	5	10	6010	01/21/00 @ 2100	RLH
Iron	5	12000	6010	01/21/00 @ 2100	RLH
Lead	5	5	6010	01/21/00 @ 2100	RLH
Magnesium	50	4600	6010	01/21/00 @ 2100	RLH
Manganese	5	160	6010	01/21/00 @ 2100	RLH
Nickel	5	22	6010	01/21/00 @ 2100	RLH
Potassium	50	920	6010	01/21/00 @ 2100	RLH
Selenium	5	<5	6020	01/28/00 @ 1904	LAB
Silver	5	<5	6010	01/21/00 @ 2100	RLH
Sodium	50	210	6010	01/21/00 @ 2100	RLH
Thallium	5	<5	6020	01/28/00 @ 1904	LAB
Zinc	5	17	6010	01/21/00 @ 2100	RLH

[1] ASA Monograph No. 9, Method 29-3.5.2.
[2] Sample digested 01/19/00 by HNO_3 Digestion.

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LABORATORY REPORT

TO: Pat Newby
ADDRESS: MT DEQ
2209 Phoenix Ave.
Helena, MT 59620

LAB NO.: 004-00-50329
DATE: 02/08/00 mf

WASTE ANALYSIS

Boulder River Site 11
Sampled 08/14/99
Submitted 01/13/00

Constituents	Detection Limit, µg/g (ppm)	Dry Weight Basis, µg/g (ppm)	EPA Method	Date & Time Analyzed	Analyst's Initials
Organic Carbon	0.02 % by wt	0.41 % by wt	(1)	01/26/00 @ 1000	SM
Total Metals[2]					
Aluminum	5	5600	6010	01/21/00 @ 2102	RLH
Antimony	5	<5	6020	01/28/00 @ 1910	LAB
Arsenic	5	<5	6020	01/28/00 @ 1910	LAB
Barium	5	60	6010	01/21/00 @ 2102	RLH
Beryllium	5	<5	6010	01/21/00 @ 2102	RLH
Cadmium	5	<5	6010	01/21/00 @ 2102	RLH
Calcium	50	3600	6010	01/21/00 @ 2102	RLH
Chromium	5	30	6010	01/21/00 @ 2102	RLH
Copper	5	9	6010	01/21/00 @ 2102	RLH
Iron	5	10000	6010	01/21/00 @ 2102	RLH
Lead	5	<5	6010	01/21/00 @ 2102	RLH
Magnesium	50	3900	6010	01/21/00 @ 2102	RLH
Manganese	5	160	6010	01/21/00 @ 2102	RLH
Nickel	5	19	6010	01/21/00 @ 2102	RLH
Potassium	50	870	6010	01/21/00 @ 2102	RLH
Selenium	5	<5	6020	01/28/00 @ 1910	LAB
Silver	5	<5	6010	01/21/00 @ 2102	RLH
Sodium	50	200	6010	01/21/00 @ 2102	RLH
Thallium	5	<5	6020	01/28/00 @ 1910	LAB
Zinc	5	19	6010	01/21/00 @ 2102	RLH

(1) ASA Monograph No. 9, Method 29-3.5.2.
(2) Sample digested 01/19/00 by HNO_3 Digestion.

ENERGY LABORATORIES, INC.
P.O. BOX 30916 • 1120 SOUTH 27TH STREET • BILLINGS, MT 59107-0916 • PHONE (406) 252-6325
FAX (406) 252-6069 • 1-800-735-4489 • E-MAIL eli@energylab.com

LABORATORY REPORT

TO: Pat Newby
ADDRESS: MT DEQ
2209 Phoenix Ave.
Helena, MT 59620

LAB NO.: 005-00-50329
DATE: 02/08/00 mf

WASTE ANALYSIS

Boulder River Site 12
Sampled 08/13/99
Submitted 01/13/00

Constituents	Detection Limit, µg/g (ppm)	Dry Weight Basis, µg/g (ppm)	EPA Method	Date & Time Analyzed	Analyst's Initials
Organic Carbon	0.02 % by wt	0.35 % by wt	(1)	01/26/00 @ 1000	SM
Total Metals(2)					
Aluminum	5	8700	6010	01/21/00 @ 2104	RLH
Antimony	5	<5	6020	01/28/00 @ 1925	LAB
Arsenic	5	<5	6020	01/28/00 @ 1925	LAB
Barium	5	85	6010	01/21/00 @ 2104	RLH
Beryllium	5	<5	6010	01/21/00 @ 2104	RLH
Cadmium	5	<5	6010	01/21/00 @ 2104	RLH
Calcium	50	3200	6010	01/21/00 @ 2104	RLH
Chromium	5	49	6010	01/21/00 @ 2104	RLH
Copper	5	11	6010	01/21/00 @ 2104	RLH
Iron	5	14000	6010	01/21/00 @ 2104	RLH
Lead	5	6	6010	01/21/00 @ 2104	RLH
Magnesium	50	5400	6010	01/21/00 @ 2104	RLH
Manganese	5	130	6010	01/21/00 @ 2104	RLH
Nickel	5	27	6010	01/21/00 @ 2104	RLH
Potassium	50	1200	6010	01/21/00 @ 2104	RLH
Selenium	5	<5	6020	01/28/00 @ 1925	LAB
Silver	5	<5	6010	01/21/00 @ 2104	RLH
Sodium	50	320	6010	01/21/00 @ 2104	RLH
Thallium	5	<5	6020	01/28/00 @ 1925	LAB
Zinc	5	24	6010	01/21/00 @ 2104	RLH

(1) ASA Monograph No. 9, Method 29-3.5.2.
(2) Sample digested 01/19/00 by HNO_3 Digestion.

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LABORATORY REPORT

TO: Pat Newby
ADDRESS: MT DEQ
2209 Phoenix Ave.
Helena, MT 59620

LAB NO.: 006-00-50329
DATE: 02/08/00 mf

WASTE ANALYSIS

Boulder River — Site 13
Sampled 08/13/99
Submitted 01/13/00

Constituents	Detection Limit, µg/g (ppm)	Dry Weight Basis, µg/g (ppm)	EPA Method	Date & Time Analyzed	Analyst's Initials
Organic Carbon	0.02 % by wt	0.33 % by wt	(1)	01/26/00 @ 1000	SM
Total Metals(2)					
Aluminum	5	9000	6010	01/21/00 @ 2108	RLH
Antimony	5	<5	6020	01/28/00 @ 1957	LAB
Arsenic	5	<5	6020	01/28/00 @ 1957	LAB
Barium	5	61	6010	01/21/00 @ 2108	RLH
Beryllium	5	<5	6010	01/21/00 @ 2108	RLH
Cadmium	5	<5	6010	01/21/00 @ 2108	RLH
Calcium	50	5300	6010	01/21/00 @ 2108	RLH
Chromium	5	26	6010	01/21/00 @ 2108	RLH
Copper	5	11	6010	01/21/00 @ 2108	RLH
Iron	5	11000	6010	01/21/00 @ 2108	RLH
Lead	5	<5	6010	01/21/00 @ 2108	RLH
Magnesium	50	3800	6010	01/21/00 @ 2108	RLH
Manganese	5	180	6010	01/21/00 @ 2108	RLH
Nickel	5	16	6010	01/21/00 @ 2108	RLH
Potassium	50	620	6010	01/21/00 @ 2108	RLH
Selenium	5	<5	6020	01/28/00 @ 1957	LAB
Silver	5	<5	6010	01/21/00 @ 2108	RLH
Sodium	50	460	6010	01/21/00 @ 2108	RLH
Thallium	5	<5	6020	01/28/00 @ 1957	LAB
Zinc	5	17	6010	01/21/00 @ 2108	RLH

(1) ASA Monograph No. 9, Method 29-3.5.2.
(2) Sample digested 01/19/00 by HNO_3 Digestion.

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LABORATORY REPORT

TO: Pat Newby
ADDRESS: MT DEQ
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LAB NO.: 007-00-50329
DATE: 02/08/00 mf

WASTE ANALYSIS

Boulder River Site 14
Sampled 08/13/99
Submitted 01/13/00

Constituents	Detection Limit, µg/g (ppm)	Dry Weight Basis, µg/g (ppm)	EPA Method	Date & Time Analyzed	Analyst's Initials
Organic Carbon	0.02 % by wt	1.39 % by wt	(1)	01/26/00 @ 1000	SM
Total Metals[2]					
Aluminum	5	11000	6010	01/21/00 @ 2114	RLH
Antimony	5	<5	6020	01/28/00 @ 1920	LAB
Arsenic	5	<5	6020	01/28/00 @ 1920	LAB
Barium	5	94	6010	01/21/00 @ 2114	RLH
Beryllium	5	<5	6010	01/21/00 @ 2114	RLH
Cadmium	5	<5	6010	01/21/00 @ 2114	RLH
Calcium	50	6400	6010	01/21/00 @ 2114	RLH
Chromium	5	41	6010	01/21/00 @ 2114	RLH
Copper	5	13	6010	01/21/00 @ 2114	RLH
Iron	5	14000	6010	01/21/00 @ 2114	RLH
Lead	5	7	6010	01/21/00 @ 2114	RLH
Magnesium	50	5700	6010	01/21/00 @ 2114	RLH
Manganese	5	180	6010	01/21/00 @ 2114	RLH
Nickel	5	24	6010	01/21/00 @ 2114	RLH
Potassium	50	1200	6010	01/21/00 @ 2114	RLH
Selenium	5	<5	6020	01/28/00 @ 1920	LAB
Silver	5	<5	6010	01/21/00 @ 2114	RLH
Sodium	50	380	6010	01/21/00 @ 2114	RLH
Thallium	5	<5	6020	01/28/00 @ 1920	LAB
Zinc	5	28	6010	01/21/00 @ 2114	RLH

(1) ASA Monograph No. 9, Method 29-3.5.2.
(2) Sample digested 01/19/00 by HNO_3 Digestion.